AGRICULTURAL ENGINEERING

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Some Engineering and Psychological Aspects of Higher Speeds - - - - - - - *E. G. McKibben*

The Problem of Designing Insulation Into Farm Buildings - - - - - - - - *G. D. Andrews*

A Discussion of Engine Fuels to Meet Farm Service Needs - - - - - - - - *Wm. Harrigan*

Recent Progress in Farm Electrification Development - - - - - - - - - - *L. J. Smith*

Moisture Equivalent, Field Capacity, and Permanent Wilting Percentage, and Their Ratios in Heavy Soils - - - - - - *Work & Lewis*

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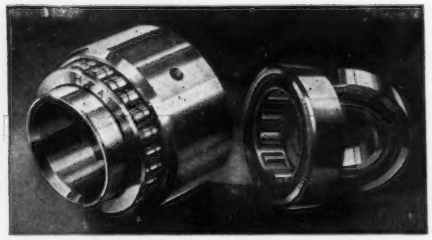

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H Y A T T

ROLLER BEARINGS

PRODUCT OF GENERAL MOTORS

Some of the Engineering and Psychological Aspects of Higher Speeds

By E. G. McKibben[1]

Introduction by D. B. Lucas[2]

"GAR WOOD Spends Years to Save Seconds" is a recent advertising headline. This one sentence expresses pointedly the emphasis which is placed on speed in modern transportation. It shows, too, the genius of the advertising man in adding drama to a fact which in itself is interesting.

The achievements of Gar Wood, like many other engineering feats and discoveries, are of great potential interest and importance. Yet all too frequently the engineer fails to interest the public in what he does. He seldom slackens his pace long enough to interpret a principle or to emphasize people in place of performance.

Professor McKibben has done more than to interpret speed in terms of human activities and emotions in this paper. He has also enriched the usual engineering concept of speed through his unique and interesting approach. We learn, for example, that a doctor may double the area in which he practices through a small increase in the speed of his automobile. At the same time we get a few hints on how to get nerve-wracking speed thrills in a properly designed contraption that could be set up in our own back yard. This paper should prove an inspiration to every engineer who is interested in the human side of his profession.—D. B. LUCAS

WHAT DOES higher speed mean to the engineer? What does it mean to the average citizen? In any emergency situation, it means a decrease in the time required for obtaining properly qualified aid. To the professional man, to the business man, to the farmer, it means a greatly increased area available in a given time, for practice, trade, or agriculture. To the foolhardy collegian, it means the possibility of a greater thrill. To the sportsman, it means new records to achieve. To the equipment designer, it means new problems to be solved. To the public safety officer and the insurance statistician, it means an increase in the index of accidents. Probably most significant of all, to the high-pressure salesman, it means just another talking point. These are just a few of the things which higher speeds may mean.

In view of the important part which increased speed is playing in all phases of our life, even agricultural production, it is fitting that engineers and psychologists give careful consideration to its benefits and possible difficulties.

Some of the important engineering relationships of the situation are shown in Table 1 and Figs. 1, 2, and 3. The most common justification given for higher speeds is the *time saved*. While there are many situations under which even a very small saving of time is of great importance, a study of horizontal rows "b" and "c" of Table 1 and the "Time" curve of Fig. 1 indicate that in some cases this idea may have been overemphasized. Equal increments of speed increase give successively smaller savings of time.

On the other hand, the increase in *area available* in a given time is seldom given sufficient consideration. As shown in row "d" of Table 1 and the "Area" curve of Fig. 1, this area increases as the square of the speed. For example, a farmer with a tractor having a top speed of 4 mph (miles per hour) has available in 15 min an area of only 2 sq mi, while with a speed of 12 mph, he could reach in 15 min any point in an area of 18 sq mi. Driving at 40 mph a veterinarian can reach in 15 min any farm in an area of 200 sq mi, while at 80 mph he can reach in the same time any animal within an area of 800 sq mi. The same relationship applies to marketing, buying,—in fact, to any professional practice or business trade area.

Against these extremely valuable and very tangible

THE INTERNAL-COMBUSTION ENGINE IS RESPONSIBLE, OR AT LEAST HAS PROVIDED THE FAVORABLE CONDITIONS, FOR THE MARKED TREND IN RECENT YEARS TOWARD HIGHER SPEEDS—ON THE FARM, AS WELL AS ON THE ROAD, ON THE WATER, AND IN THE AIR. AS MR. MCKIBBEN POINTS OUT IN THE ACCOMPANYING ARTICLE, IN VIEW OF THE IMPORTANT PART WHICH INCREASED SPEED PLAYS IN ALL PHASES OF DAILY LIFE, EVEN AGRICULTURAL PRODUCTION, IT IS FITTING THAT ENGINEERS AND PSYCHOLOGISTS GIVE CAREFUL ATTENTION TO ITS BENEFITS AND POSSIBLE DIFFICULTIES

[1]Associate professor of agricultural engineering, Iowa State College. Mem. A.S.A.E.

[2]Associate professor of marketing, New York University. Mem. A.S.A.E.

TABLE I. SOME ENGINEERING RELATIONSHIPS OF SPEED

		Formula													
(a)	Miles per hour	S	1	2	3	4	5	6	8	10	20	30	40	50	60	70
(b)	Minutes per mile	$60/S$	60	30	20	15	12	10	7.5	6	3	2	1.5	1.2	1.0	0.86
(c)	Minutes saved per mile by increased speed			30	10	5.0	3.0	2.0	2.5	1.5	3.0	1.0	0.5	0.3	0.2	0.14
(d)	Square miles available in one hour	$2S^2$	2	8	18	32	50	72	128	200	800	1800	3200	5000	7200	9800
(e)	Feet per second	$1.467S$	1.5	2.9	4.4	5.9	7.3	8.8	11.7	14.7	29.3	44.0	58.7	73.4	88.0	102.7
(f)	Seconds per 100 feet	$68.18/S$	68.2	34.1	22.7	17.0	13.6	11.3	8.5	6.81	3.41	2.27	1.70	1.36	1.13	0.97
(g)	Foot-pounds of kinetic energy per pound	$0.0334S^2$	0.033	0.134	0.301	0.535	0.836	1.203	2.139	3.343	13.37	30.08	53.49	83.57	120.3	163.7
(h)	Pounds force required to stop 150 lb man in 10 ft	$0.5014S^2$	0.5	2.0	4.5	8.0	12.5	18.0	32.1	50.1	200.6	451.3	802.3	1253.7	1805.2	2455.8
(i)	Pounds force required to stop 150-lb man in 1 ft	$5.014S^2$	5.0	20.1	45.1	80.2	125.4	180.5	320.9	501.4	2006	4513	8023	12537	18052	24558
(j)	Feet required for stopping by force of 50 per cent of weight	$0.0669S^2$	0.067	0.267	0.602	1.069	1.671	2.407	4.279	6.69	26.74	60.17	107.0	167.1	240.7	327.4

benefits of time saving and operating area increase, society and the individual must balance certain difficulties which inevitably accompany any appreciable increase in speeds.

Higher speeds require *better design* and *better materials*. This means higher first cost for equipment. If the increased accomplishment resulting from higher speeds does not keep pace with the increased first cost, the result will be higher depreciation and interest costs per unit of distance traveled.

Higher speeds mean *greater probable wear* and *tear*. These maintenance costs may or may not increase more rapidly than the output. In general, the forces causing this increased wear and tear increase as the square of the speed rather than as the speed. Many farmers have been surprised at the damage resulting from the trailing of a machine, designed for use at 2 to 3 mph, behind a truck or automobile at what seemed (in the rubber-tired vehicle) the very slow speeds of 10 to 15 mph. If they had ridden on the steel-wheeled, springless machine instead of in the automobile with its shock insulation of rubber and springs, they would not have been surprised. The speed was increased only five times, but the road shocks were probably increased five times five or twenty-five times. Thus, there is always the possibility that repair costs may be higher per unit of distance traveled.

If the speeds are high enough to make *air resistance* an important consideration, this resistance will be found to increase approximately as the square of the speed. Therefore, at very high speeds it becomes a very important factor.

Thus, it is possible to have the benefits of higher speeds largely nullified by the resulting increased costs.

As speeds are increased the item of *safety*, both individual and public, becomes of increasing importance. The rapidly *decreasing time* and *increasing energy* make *adequate control* a matter of very serious concern to all. This situation is shown in rows "f" and "g" of Table 1, the "Time" curve of Fig. 2 and scale "A" of Fig. 3. The significance of the foot-pounds of kinetic energy per pound of weight shown in row "g" of Table 1 and by scale "A" of Fig. 4, is more easily understood by keeping in mind that the same energy situation would be obtained by dropping an object from or jumping off an elevation of the same height. For example, suddenly stopping a tractor which is moving at 10 mph presents the same difficulties as would result from dropping it a distance of three feet. When as the result of some unfortunate circumstance a man traveling at 80 mph is suddenly confronted with a telephone pole, bridge railing, or some other solid and at the moment unavoidable obstruction, he is in about the same predicament as he would be at the end of a dive from a 200-ft building. His chances are largely a matter of how solid the obstruction is.

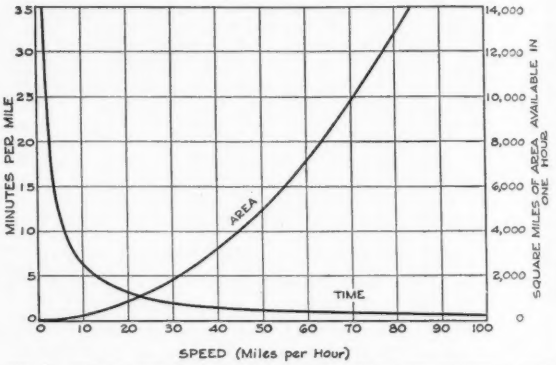


FIG. 1 EFFECT OF SPEED UPON TIME REQUIRED TO TRAVEL A MILE AND THE AREA AVAILABLE IN ONE HOUR

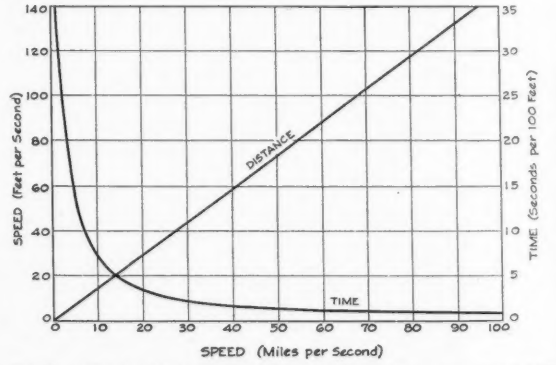


FIG. 2 OTHER MORE SIGNIFICANT TERMS FOR SPEED, AT LEAST FROM THE VIEWPOINT OF SAFETY

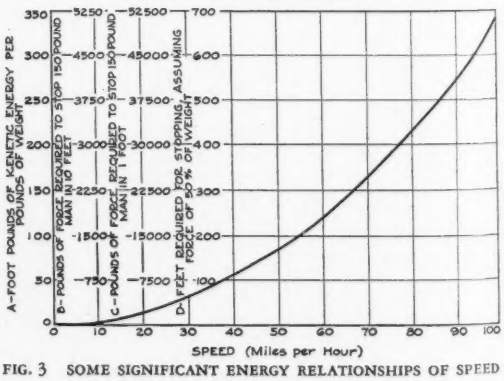

A-FOOT POUNDS OF KINETIC ENERGY PER POUND OF WEIGHT
B-POUNDS OF FORCE REQUIRED TO STOP 150 POUND MAN IN 10 FEET
C-POUNDS OF FORCE REQUIRED TO STOP 150 POUND MAN IN 1 FOOT
D-FEET REQUIRED FOR STOPPING, ASSUMING FORCE OF 50% OF WEIGHT
SPEED (Miles per Hour)

FIG. 3 SOME SIGNIFICANT ENERGY RELATIONSHIPS OF SPEED

The forces required for the stopping of a 150-lb man in ten feet and one foot are shown in rows "h" and "i" of Table 1 and scales "B" and "C" of Fig. 3. At higher speeds these forces become almost unbelievable. They easily explain the disastrous results frequently witnessed after a forced sudden stop.

Row "j" of Table 1 and scale "D" of Fig. 4 give the distance required for the satisfactory stopping of high-velocity vehicles with an average force of one-half of the weight of the vehicle. While good brakes on a good pavement can do somewhat better than this, a total retarding force of about one-half of the vehicle's weight is about all the motorist should expect. If a sudden stop is to be made at such speeds, something besides friction must be involved. That something is usually a destructive collision.

In addition to these easily calculated engineering relationships, there are a number of *psychological factors* which must be given due consideration. Since they are based primarily on emotion rather than reason, they are more difficult to analyze and frequently tend to nullify the reasoned conclusions reached after a logical consideration of the engineering relationships. There is abundant evidence that to many members of society the thrill of rapid motion, of the gamble with the possibility of a fatal accident, or of setting a new record all offer an urge against which the best of logic carries but little weight.

However, not all members of society enjoy such thrills. Some wish to travel at high speed in order to save time or increase their operating area, but wish to do so as quietly, safely, and comfortably as possible. Since the thrill of speed is largely a matter of atmosphere and apparent rather than real motion, that is, a matter of noise, of vibration, of closeness of passing objects, of the wind blowing through one's hair, if you please, a high-speed machine designed to be satisfactory to most of society's conservative members must be driven still faster to satisfy the more primitive urges of our more reckless, foolhardy, restless, vital, enthusiastic (whatever adjective you prefer) friends. Thus an endless cycle is started. This still faster machine must be made to appear safe to our more cautious, sensible, timid, killjoy (again whatever adjective you prefer) friends, and again to get the desired sensation, it must be forced to yet higher speeds by the other group. In this way the American type of civilization progresses, at least keeps in rapid motion.

Instruction in the Use of Explosives

SOME of the reasons for giving instruction in the use of explosives a regular place in the curriculum lie more in the realm of feeling than of reason. Far from ruling out such reasons, we should assign them added weight, commensurate with the dominance of emotion in controlling human action.

It seems a subconsciously foregone conclusion, an emotional assumption, that blasting is like snake-charming or lion-taming; something done with comparative impunity by few persons, and in their cases mainly by weird gifts and good luck. It—or they—has been felt as socially tolerable, but nothing to teach in school, nothing to be generally accepted or practiced. Wholly apart from the subject matter or its method of presentation, the mere fact of routine inclusion in the curriculum will do much to blast out this emotional attitude, to uproot the feeling that explosives are for someone else to use on some other job.

Instruction in blasting, in at least its economic phases, should not be limited to students in land reclamation. That prospective management engineers should be conversant with the capabilities and limitations of explosives is obvious. Power and machinery men all too often may fail to recognize the point at which powder and cap become more efficient than power and tool.

Once we decide to teach all engineers the economics and application of explosive practice, we may as well drop distinctions and include for all students the field practice in blasting procedure. The amount of time required is not prohibitive. The subject matter is spectacular and bound to make its impression by every avenue of sense, save possibly that of taste. The mere gesture of assuming the active voice in placing a charge or lighting a fuse may be just what is needed to push over the mental barrier that seems to exist.

Thus far education in blasting practice has been carried on largely by the explosives manufacturers, and charged up to advertising or sales expense in some guise or other. It is not at all a reflection on the job they have done to suggest that education is best done by educators. If anything, the fact that industry has done a creditable job of education is a hint that the regular educational machinery has left it undone.

The balanced viewpoint would seem to demand that explosives practice be built into the subject matter of organized agricultural engineering education, correlating it at every point with the other phases or branches of that subject matter.—W. B. JONES

(LEFT) BLASTING A NEST OF BOULDERS NOT EASILY PULLED BY A TRACTOR UNTIL SUFFICIENTLY DISLODGED. (RIGHT) LEDGES AND BOULDERS REDUCED BY BLASTING

Designing Insulation into Farm Buildings[1]

By G. D. Andrews[2]

IN THE DESIGN of the farm home or other building employing artificial heat, it is customary to estimate the heat losses from such buildings during extreme weather conditions and to supply a heating plant capable of supplying the necessary heat to maintain desired inside temperatures.

To do this, data concerning the outside conditions, the building construction, and the inside conditions are tabulated and expressed by the formula

$$H = A\,U\,(t_1 - t_o) + \frac{I\,(t_1 - t_o)}{53} + \frac{V\,(t_1 - t_o)}{53}$$

where H = Total Btu (British thermal units) per hour required to maintain a specific inside temperature
A = Area in square feet of net inside or heated surfaces of walls, glass, roof, and floor
U = Coefficient of heat transmission (per hour per degree per square foot)
$(t_1 - t_o)$ = Design temperature difference
I = Cubic feet of air per hour admitted to building by infiltration through cracks and crevices
V = Cubic feet of air admitted per hour for ventilation
53 = Cubic feet of air raised one degree by one Btu.

Because of the nature of the problem, extreme precision in estimating such losses is unlikely. However, the data is sufficiently accurate so that the formula is practical for the determination of heating and air-conditioning units. Likewise, in the refrigeration and cold storage fields a modification of the formula permits the installation of refrigerating equipment of correct capacity that is therefore economical and satisfactory.

The mechanical equipment used in heating, cooling, and refrigerating can be tested for production and a marginal safety factor provided to care for extreme conditions. This permits some leeway to the designer.

That this formula is applicable to any farm building which houses livestock and poultry can be easily ascertained by applying it to specific buildings now existing. And, in the design of new buildings, it is but necessary to build the walls, windows, doors, roofs, and floors around the heating plant, i.e., the livestock and poultry to be housed, and to effect temperature control by the ventilation systems.

The leeway permitted in the design of homes and commercial buildings is somewhat greater than that allowed the agricultural engineer, who must rely on the body heat production of livestock and poultry. The safety factor must be included in the building of the walls, roofs, etc. It is here that cost enters into the picture. It is here, also, that insulation becomes a significant economical factor. A farm building acceptable to the average farmer must provide a practical degree of temperature control and ventilation at the least possible cost; and this must be a cost the farmer can afford.

A practical design must be so fundamentally correct in specifications that to cut those specifications would be impossible, if correct conditions were to obtain, and to enlarge upon those specifications would but give greater limits of control.

Opinions may differ widely on what is a practical degree of temperature control to build into a livestock and poultry shelter. In the case of dairy barns where the amount of heat produced in relation to the area of wall, ceiling, windows and doors is large, resistance to heat loss can be built into those areas at a small cost per head to give temperature control and practical ventilation at great temperature differences. In the case of hog houses and poultry houses where less heat is produced in relation to the inclosing areas, greater resistance to heat loss must be built into those areas.

Probably it will be necessary, in the case of hog and poultry houses, to design them for average winter conditions and to specify a small stove or heater to be used during extreme weather of short duration. As an example of the application of the formula to a particular design, a 20x20-ft shed-type poultry house has been selected. From the standpoint of material and labor cost, this size and type of poultry house can be framed in at the least cost per square foot of floor area inclosed. The framing also presents the least practicable areas of walls and roof to cover with materials. Therefore, if this framing is covered with building materials of sufficient efficiency to conserve, to a practical extent, the heat produced by the birds confined, it follows that it will be the lowest cost practical poultry house.

The problem then is to discover the required heat resistance to build into the walls and roof; and we assemble our data as follows:

Outside Conditions (The Weather). Assuming the location of the poultry house in the extreme climate of Temperature Zone 1 (USDA temperature zone map and data), let us assume as practical a design temperature of 5 deg F as the average normal temperature, with —10 deg F as the extreme average temperature; a 15-mph wind; and, as a further factor of safety in estimating the ventilating requirements, that outside air will be saturated (100 per cent humidity).

Building Construction. A shed-type poultry house 20x 20 ft, with 8 ft front and 5-ft rear walls, has been selected, and the following details of construction assumed:

1 Foundation wall of 6-in concrete
2 Floor of 4-in concrete on suitable fill poured in two courses with water proof felt between
3 Framing consisting of 2x4 sills, plates, and studs, and 2x6-in rafters with 2x6-in purloin and purloin post at midpoint of roof
4 Wall and roof materials to be determined
5 Windows: (Front) Three each consisting of two sash, six lights, 10x12-in glass. (Rear) Three cellar sash, three lights, 9x12-in glass
6 Door (one), 2 ft 6 in by 6 ft 6 in
7 Ventilating system consisting of one centrally located outtake flue 20x20 in extending from a point 14 in above the floor to 12 in above the highest point of the roof, supported by the purloin and purloin post
8 Four fresh air intakes (manual control), two located in front wall and two located in rear wall and ceiling; intakes designed to admit air at ceiling.

[1]Paper presented before the Farm Structures Division at the 28th annual meeting of the American Society of Agricultural Engineers, at Detroit, Michigan, June 1934.

[2]Farm field representative, The Celotex Co.

(It is assumed that it is both possible and practical to manipulate the dampers on this system to regulate the amount of ventilation and that temperature control can be regulated with it.)

Inside Conditions. It is proposed to house in this building 150 White Leghorn hens averaging four pounds per hen. The lowest temperature desired is assumed to be 32 deg F, and the highest per cent of humidity of the inside air, 75 per cent. From data given in the bulletin, entitled "Estimated Data on the Energy, Gaseous, and Water Metabolism of Poultry for Use in Planning the Ventilation of Poultry Houses," by H. H. Mitchell and M. A. R. Kelley (Key No. 111.-57), we find that the heat produced at 32 deg F by these 150 White Leghorns would be 5414 Btu per hour. As a safety factor we have disregarded the extra heat available given in Table 4 of the bulletin.

Also, assuming outside air at 5 deg F saturated, it will require 20 cu ft per hen per hour to remove moisture produced by the hens and maintain 75 per cent relative humidity.

All coefficients of transmission used will be those recommended by the American Society of Heating and Ventilating Engineers as published in their Guide for 1934, chapter 5, table 7. In the absence of definite tests on poultry house windows, values will be taken for poorly hung residence windows from the Guide. Some leeway is permissible due to the "take up" possible by regulation of the ventilating system.

In undertaking the solution of the problem in hand, it is required to determine U_1, the coefficient of transmission of wall and roof, and this is accomplished by the application of the following formula:

$$H = (A_1U_1 + A_2U_2 + A_3U_3 + A_4U_4) \times (t_1 - t_0) + \frac{I\,(t_1 - t_0)}{53} + \frac{V\,(t_1 - t_0)}{53}$$

where $H = 5414$ Btu per hour

A_1U_1 = Net wall and roof area × coefficient = 867 U_1 (U_1 is wanted)

A_2U_2 = Net glass area × coefficient = 36.7 × 0.45 = 16.5

A_3U_3 = Net door area × coefficient = 16.7 × 0.46 = 7.7

A_4U_4 = Net floor area (disregarded; floor discussed below)

I_1 (window infiltration) = 79 (lin ft crack) × 39.3 × 50% × 50% = 776 cu ft per hr

I_2 (door infiltration) = 18.25 (lin ft crack) × 78.6 × 50% = 718 cu ft per hr

I = Total infiltration = 1494 cu ft per hr

$V = 3000 - 1494 = 1506$ cu ft per hr

$t_1 - t_0 = 27$ deg F temperature difference.

Substituting in the formula,

$$5414 = (867\,U_1 \times 27) + \left(16.5 + 7.7 + \frac{1494}{53} + \frac{1506}{53}\right) \times 27$$

$$23{,}409\,U_1 = 5414 - 2178$$

$$U_1 = 0.138$$

(In the foregoing example, the factor of the floor has been disregarded. It is significant to note that in residence and commercial, as well as in cold storage construction a floor built on the ground is considered. The transmission factor of the floor is figured and a plus or minus Btu is accordingly estimated. When the floors of poultry houses are above ground, this factor must be included in the formula since it then becomes a known factor.)

It now remains to specify a wall and roof to meet this efficiency. Example (using $r = 1/U$):

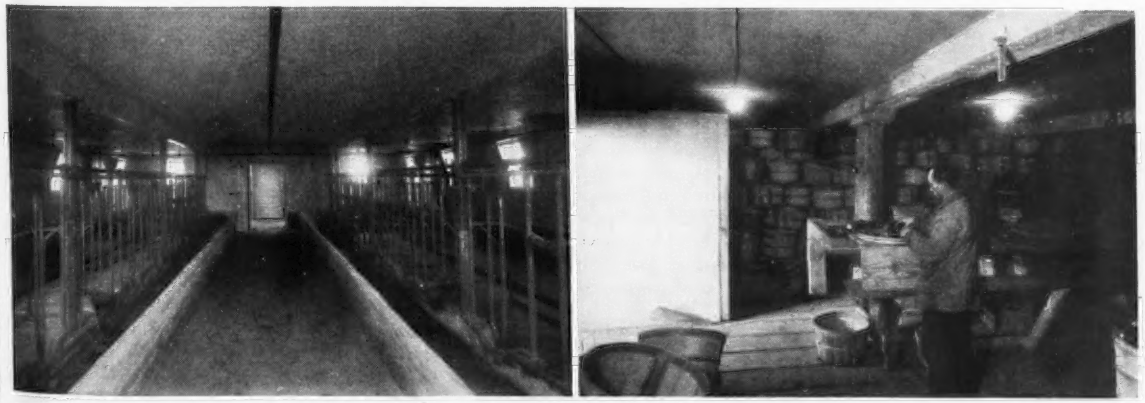
Outside air	0.167
Matched siding (25/32 in)	0.980
½-in Celotex	1.515
Air space between studs and rafters	0.909
1-in Celotex	3.030
Inside air	0.606
	7.207

$U = 0.138$

Knowing the required heat-stop efficiency of any wall or roof, it is possible to substitute the values of different materials in determining the lowest cost wall and roof. It requires but little investigation to discover the real economic significance of insulation.

The various products on the market include board, quilt, batt, fill, and foil insulations. Undoubtedly there are some places best suited for each and some places where combinations will prove economical. The engineer must take into consideration many things in solving the various problems facing him in designing new or remodelling old farm buildings.

From the A.S.H. & V.E. 1934 Guide, page 77, attention is called to the fact that conductivities per inch of thickness of materials or insulations do not afford a true basis for comparison, although they are frequently used for that purpose. Correct comparisons should take into consideration many different factors, including conductivities or conductances, thicknesses installed and manner of installation, while the selection of an insulation should also give consideration to structural qualities, as well as material and



(LEFT) AN IOWA DAIRY BARN INSULATED WITH CELOTEX BUILDING BOARD. (RIGHT) PENNSYLVANIA APPLE STORAGE CELOTEX INSULATED

application costs. Fire, vermin, and rot resistance are other important factors to consider in comparing materials.

In conclusion, the application of the formula to many types of farm structures should determine the necessity and the economy of insulation. It should reduce the designing of farm buildings to a more exact basis. It should also provide a good measuring stick for present plans and point the way to research, and therefore to betterment in many designs.

Engine Fuels to Meet Farm Service[1]

By William Harrigan[2]

TODAY the petroleum industry, under the existing petroleum code, is enjoying what promises to be, in a broad sense, a return of good business.

This statement must not be misconstrued to mean that there are not many important problems still to be satisfactorily handled, but rather that the industry as a whole appreciates the importance of the principle that cooperation on a broad ethical basis is the surest method to correct evils and bring about mutual prosperity.

The bootlegger selling "gyp" gasoline has been the scourge of the legitimate retail marketer. Selling to consumers at the wholesale price of the gasoline and retaining as profit the uncollected federal and state tax, which in many cases often is more than the margin of profit an honest dealer can possibly make, has resulted in demoralizing the gasoline markets during the past few years. The bootleggers and their companions have sold from ten to twenty per cent of the gasoline requirements of the country and swindled the government, both federal and state, out of millions of dollars in revenue.

We still have some gasoline bootlegging, and of course there is a great deal of "hot oil" being shipped, but the petroleum industry is very hopeful that soon this will be brought to an end under the present federal set-up.

During the past few years all sense of proportion of values as applied to petroleum seems to have been lost. Tremendous resources of crude oil have resulted in a mad endeavor to convert this commodity as quickly as possible into gasoline—and cash. As to by-products, there were few, the idea being to sell that portion of the crude oil not suitable for gasoline at any cost for ship bunkers, Diesel fuel, furnace oil, etc.; this results in an unbalanced idea as to the true value of the oil so recklessly thrown away.

This condition could not go on forever; someone just had to have the courage to stop the waste of one of the country's most needed natural resources. In the event of war, the nation's strength is no greater than its available supply of petroleum.

If, therefore, we may reasonably expect a saner and more logical control of petroleum and its several important subdivisions, such as gasoline, kerosene, distillates and the heavier portions, it is quite impossible to judge accurately the relative values by using former price schedules or rate indices, but rather the question revolves around the important law of supply and demand.

The greatest demand at present is for gasoline; and it is quite possible for some time to come that any proration of crude will be guided largely by the gasoline requirements of the country based on average gasoline yields per barrel of crude oil. This will naturally lead refiners to improve their methods so as to secure as large a share of the gasoline possibilities of a barrel of crude as possible, with the result that the remaining heavier fractions of crude will become less and their market value be increased accordingly.

The first call on the heavy portions of crude not used for gasoline, namely, kerosene, light distillates, and lubricating oil, will naturally be for the United States Navy and the merchant marine; the second call will be for vessels fueling at points where fuel oil may be handled advantageously, and third call will be for railroads taking on Diesel oil at oil-handling terminals. It may be of interest to note, in this connection, that many railroads about to Dieselize their trains are inquiring with a view to taking all the available Diesel oil of many refiners, and, because of the convenience of handling, this business is looked upon with favor by refiners.

Every ten years or so there is a movement on the part of many large users of electric power, such as hospitals, office buildings, etc., to install their own power and electric lighting plants. We are at present witnessing the beginning of such a trend, and the source of power in most places will be Diesel engines. Every one of these engines installed will be a factor in absorbing the limited supply of fuel oil which I believe will soon exist.

Next, let us try to visualize the evergrowing demand for furnace oil to supply the large number of oil furnaces now being installed in public and private buildings—a growing volume increasing at the rate of 1,000 oil burners a day.

What is the price situation? What establishes the cost of petroleum products? We know it reflects the factor of supply and demand; it also includes the cost of handling the crude, its refining and distribution.

Too often, when comparing the relative cuts or fractions of crude, commentators do not make a fair comparison. Very often comparison of the wholesale price of one with the retail price of another is erroneously made. Delivered in similar quantities, the true cost of all fuel suitable for industrial or agricultural service, whether it be gasoline, kerosene, or fuel oil, should be about the same, subject of course to the addition of federal or state taxes to those fuels which are taxable.

The point I wish to make is that, in my opinion, the cost of petroleum fuel over a wide distillation range will soon approach a uniform price for given delivered quantities. It therefore behooves the engineering talent of the nation to design engines, whether Diesel, kerosene, or gasoline, that will produce the most satisfactory and economical power, taking into consideration all the factors, such as initial cost, maintenance cost, ratio of power to weight, hours of service, as well as fuel and oil consumption costs per unit of work.

The engine fuel for farm requirements will be whatever engine designers are able to prove is needed. However, I state as a personal observation that the designers should consider fuel costs of all grades of fuel on an equal basis, allowing no differential in price between gasoline, kerosene, or fuel oil; for if they do not, changing prices and taxation on fuels now exempt may prove resistance points difficult to overcome.

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[1]Paper presented at a session of the Power and Machinery Division of the American Society of Agricultural Engineers during the 28th annual meeting of the Society held at Detroit, Michigan, June 1934.

[2]Supervisor, manufacturers service, The Texas Company. Mem. A.S.A.E.

The Influence of the Diameter of a Cylindrical Well Upon the Quantity of Water Produced[1]

By Willard Gardner and Clark Affleck[2]

IN THE December 1933 number of AGRICULTURAL ENGINEERING, Farr and Gardner introduced the equation

$$Q = p\,R_e \qquad [1]$$

as a first approximation for the relation between the quantity of water, Q, flowing into a cylindrical well and the radius, R_e, of the well, p representing a proportionality constant. In the April 1934 number, M. R. Lewis suggests that this assumption is not in keeping with the original equation,

$$Q = \frac{CH}{ln\ R/R_e} \qquad [2]$$

resulting from Darcy's law. In this equation H represents the elevation above the surface of the water in the well of the piezometric surface (designated *virtual* in the diagram) at the distance R from the axis of the well.

Treating H and R as constant and differentiating leads to

$$(dQ/Q)/dR_e = Q/(R_eCH) = \frac{1}{R_e\ ln\ R/R_e} \qquad [3]$$

If Q is small with H large, it follows from equation 2 that R must be large compared with R_e, and from equation 3 that the fractional increase in Q with increase in R_e must be small. In theoretical discussions in the literature, the quantity R has been taken relatively large and referred to as the radius of the "circle of influence," and the conclusion has been drawn and applied generally that increasing the size of the well exercises very little influence on the quantity of water produced for a given drawdown, except in so far as it affects the friction in the well itself.

It should be observed that, if the confining layers are impermeable, the radius of the "zone of influence" might be almost anything, depending entirely upon the physical factors which determine the so-called boundary conditions, and it seems therefore an arbitrary procedure to force the conclusion that the size of the well has little influence on the quantity of water produced.

Furthermore, although the ideal equation (equation 2) is useful for many calculations, it should not be forgotten that leakage to or from relatively impervious strata overlying the water-bearing gravel may exert considerable influence upon the performance of any actual well. The development to follow may throw some light on this question.

Disregarding the effect of leakage from or into the clay underlying the gravel and making certain simplifying assumptions, a modified form of this equation may be derived thus:

Let h = the elevation from the top of the gravel of the actual piezometric surface at the distance R from the axis of the well

k = the transmission constant for the gravel

k_c = the transmission constant for the overlying clay

Q = the horizontal flow in the gravel at the cylindrical surface of radius, R, regarded now as a function of R

w = the thickness of the clay

l = the thickness of the gravel.

The upward leakage from the gravel into the element of overlying clay of differential area $2\pi R(dR)$ will then be

$$dQ = (2\pi R dR)\,\rho k_c g[(h-w)/w], \qquad [4]$$

the factor $k_c g[(h-w)/w]$ representing the velocity obtained from Darcy's equation. This will correspond with the increase in horizontal flow in the gravel at the cylinder of radius $R + dR$ over that of radius R. Thus

$$dQ = d[2\pi Rl\rho gk(dh/dR)]$$

$$= 2\pi l\rho gk\left(R\frac{d^2h}{dR^2} + \frac{dh}{dR}\right)dR. \qquad [5]$$

Equating right-hand members of equations 4 and 5, we obtain

$$\frac{Rk_c}{lk}\left(\frac{h-w}{w}\right) = \left(R\frac{d^2h}{dR^2} + \frac{dh}{dR}\right) \qquad [6]$$

This equation is linear and its solution involves the solution of the abridged equation

$$\frac{d^2h}{dR^2} + \frac{l}{R}\frac{dh}{dR} - \frac{k_c h}{lkw} = 0. \qquad [7]$$

This is a special case of Bessel's equation, and the following converging series is found to satisfy it:

$$h_1 = 1 + \frac{ar^2}{2^2} + \frac{a^2r^4}{2^2 4^2} + \frac{a^3r^6}{2^2 4^2 0^2} + \ldots\ldots \qquad [8]$$

where $a = k_c/lkw.$ [9]

This leads to the following approximate solution of equation 6:

$$h = \gamma/4 + w + \frac{awr^2}{12} + [\gamma/6 + (2/9)w](l/x)$$

$$+ (\gamma/2)x + [C - (\gamma/2)\ ln\ (x/r^2)]x^2 \qquad [10]$$

where x is defined thus

$$x = [1 + (a/2)r^2] \qquad [11]$$

and γ and C are integration constants having the dimensions of length.

The constants of equations 2 and 10 were given such arbitrary values as to make their graphs pass through the

[1]Contribution from the Department of Physics, Utah Agricultural Experiment Station. Publication authorized by the Director, July 25, 1934.

[2]Physicist and graduate assistant, respectively, Utah Agricultural Experiment Station.

same point at the well, to determine the same flow into the well, and to cut the surface of the ground near the well. The curves are shown in the accompanying diagram. From the well to the point where these surfaces cut the surface of the ground the quantity h—w is negative and the leakage is negative,—that is, it is into the gravel from the clay. Beyond this point it is positive, and at some critical point the slopes of the actual and the virtual curves will be the same. Beyond this critical point the slope of the actual curve will remain larger than for the other. If the actual surface does not cut the surface of the ground, the leakage is everywhere negative.

Inasmuch as the flow into the well represents either a direct contribution from the overlying clay or a cutting down of the leakage into the clay, it would be more appropriate to differentiate the definite integral taken over the surface of contact between the two strata in order to estimate the relation between Q and R_e than to differentiate equation 2. The integrand of this integral is obtained from equation 4, and the derivative becomes

$$dQ/dR_e = -\frac{d}{dR_e}[(2\pi\rho k_e g)/w]\int_{R_e}^{L}(h-w)RdR$$
$$= -[(2\pi\rho k_e g)/w]\times$$
$$\left[\int_{R_e}^{L}(\partial h/\partial R_e)RdR - R_e(h-w)_{R_e}\right] \quad [12]$$

The partial derivative $\partial h/\partial R_e$ is negative. When $R = O$, it appears to be infinite, and when R is large, it becomes very small. It would seem logical, therefore, as a first approximation, to make the substitution

$$\partial h/\partial R_e = -C/R. \quad [13]$$

With this substitution equation 12 reduces to

$$dQ/dR_e = \frac{2\pi\rho k_e g CL}{w} + \frac{2\pi\rho\rho k_e g R_e}{w}(h-w-C)_{R_e} \quad [14]$$

Introducing now the abbreviated notation

$$p = \frac{2\pi\rho k_e g CL}{w} \quad [15]$$

and $$B = \frac{(C+w-h)_{R_e}}{2}\times\frac{2\pi\rho k_e g}{w} \quad [16]$$

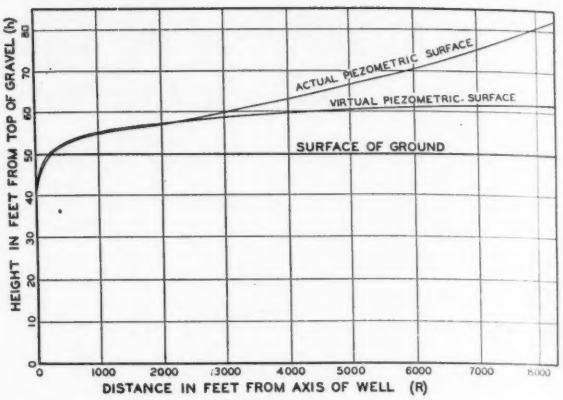
we obtain $dQ/dR_e = p - 2BR_e$ [17]

which becomes when integrated

$$Q = A + pR_e - BR_e^2. \quad [18]$$

Obviously the constant A is zero and B small compared with p.

The upper limit, L, of the definite integral of equation 12 is presumed to be taken large. If it represents the radius of a "circle of influence," then it would seem that the validity of equation 18 rests primarily on the assumption introduced in equation 13, and if this assumption is approximately near the truth, then also equation 18, with


HEIGHT IN FEET FROM TOP OF GRAVEL (h)
ACTUAL PIEZOMETRIC SURFACE
VIRTUAL PIEZOMETRIC SURFACE
SURFACE OF GROUND
DISTANCE IN FEET FROM AXIS OF WELL (R)

B small compared with p, must be a reasonably close approximation. The right-hand member of this equation appears to represent the first three terms of a power series, and it seems probable that for high precision additional terms might be necessary. It may be in order to repeat, however, that actual boundary conditions must furnish the correct answer to this question in any given case.

Engineering Terminology

MANY mechanical engineers have a feeling of keen appreciation of the homely but expressive terminology of their technical language. The carriage and the apron of a lathe, the bed of a machine, wristpin, rat-tail file, such simple and appropriate designations as jet and surface condenser, V-threads, knee, saddle, and column, realistically applied to machine elements, cone pulley, spur gear, cross-cut and rip saws, live and dead centers, spark plug, butterfly valve, D-slide valve, and a host of other terms come readily to mind and indicate their humble origin amid craftsmen who applied familiar words that fitted naturally. No hobgoblin of consistency bothered the minds of those who chose these names; no etymologist was consulted; no scheme of latinized surnames to honor a discoverer and confuse a student was attempted. Even scientifically minded Watt hit upon so apt a term as horsepower, the virility of which is attested by its persistence even when applied to boiler capacity. A non-technical person can visualize a horsepower and the term foot-pound has utility, but kilowatt and erg have significance only to those who are in the know.

It seems that two principles are involved. One is that the advance of technology has so far outrun the terminology that the old terms become inadequate and need careful qualification or even substitute expressions to insure clarity and accuracy. From the point of view of young men studying engineering, much is to be gained by insisting on accurate terminology and an avoidance of words that have confusing connotations. On the other hand it is well to avoid pedantry and fussiness that insist on tiresome and unnecessary precision.

After all, it is a good rule to follow in any kind of writing to use the most accurate and appropriate term and to avoid pedantic fussiness. We shall find, as engineering grows, that we shall need new and more accurate terminology. . . . . And without losing the richness of our language, let us not be afraid to make use of new and correct terms. —From an editorial in the August 1934 "Mechanical Engineering."

Moisture Equivalent, Field Capacity, and Permanent Wilting Percentage and Their Ratios in Heavy Soils[1]

By R. A. Work[2] and M. R. Lewis[3]

INTELLIGENTLY applied irrigation practice depends primarily on a knowledge of the characteristics of the soil irrigated. Among the most important of these are (a) the quantity of water stored in the soil from an application of irrigation water, i.e., the *field capacity*; (b) the quantity of water which will remain in the soil when plants have withdrawn all they can without permanently wilting, the *permanent wilting percentage* (11)[4] and (c) the difference between those two quantities or the maximum quantity of water the soil will hold in a form available to plants, the *available capacity*. The moisture equivalent is perhaps the best known and most useful of the many single-value functions descriptive of the water relations of a soil that may readily and quickly be determined in the laboratory. It is the purpose of this paper to report results of studies concerning soil moisture constants and their ratios, as determined for slightly pervious clay soils at Medford, Oregon.

Irrigation experiments were initiated on two orchards, known as the Fitch and the Klamath orchards, in 1930 and conducted throughout that and the two following years through the courtesy of the owners. During 1932 additional and more detailed experiments, dealing with soil moisture and the response of pear trees thereto, were started at the Medford experiment station.

The climate of the Medford area is semiarid. The normal annual rainfall is 18-14 in, with only 1.85 in occurring from June to September, inclusive.

Soils. The soil type at the Fitch orchard is Meyer silty clay loam (7). It consists of a light brown to reddish brown sticky, silty clay loam, approximately 24 in in depth, resting on a yellowish brown clay subsoil. The subsoil rests on sandstone at depths of from 4 to 6 ft. The subsoil has been derived in large part by weathering of the parent rock in places, but the surface horizon appears to be partly derived from upper slopes by creep or slipping, washing by rains, or other agencies. Percentages obtained in making mechanical analyses of typical samples of this soil type are as follows (8):

Horizon	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
A	1.8	3.7	3.0	7.9	8.0	52.1	23.3
B	4.6	6.5	5.0	10.4	11.7	34.9	26.9

The soil type at the Klamath orchard and the Medford station is Meyer clay adobe. It consists of a dark brown to nearly black clay, of pronounced adobe structure, from 4 to 6 ft deep. The soil structure and texture appear to be quite uniform at all depths below the first foot down to the horizon of disintegrated parent material just above the rock, which is a shale. Continuous winter cover cropping for some years appears to have influenced the structure of the upper few inches. The color grades into yellow with increased depth. The soil appears to be largely residual in origin. A mechanical analysis of a typical sample of this soil type shows percentages as follows (8):

Horizon	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
A	1.3	3.1	3.3	6.4	6.3	27.6	51.8

A sample of the surface 6 in of the Meyer clay adobe taken from a field at the Medford station adjoining the plots had the following percentages by mechanical analys's (6): Total sand, 36.4; silt, 25.5; and clay, 38.1.

The water table was below the surface of the bedrock at all times, except occasionally after a heavy irrigation or after prolonged winter precipitation. In the Klamath and Medford station orchards a perched water table a few inches above the bedrock was observed under these conditions for periods lasting up to a week.

In the Fitch orchard the four plots adjoined each other and each contained an area of 0.33 acre. In the Klamath orchard the aggregate area of the four adjacent plots was 0.85 acre. At the Medford station the average area of each plot was 0.88 acre. The last-named plots adjoined each other and each was subdivided into halves.

In the Fitch and Klamath orchards each plot contained five permanently located points of sampling, each representing one-fifth of the plot. On the Medford station the same plan of location was used but each location was quadrupled, thus giving 20 points of sampling in each plot and 10 points of sampling in each half of each plot. In the subsequent discussion the plot halves at the Medford Station are referred to as plots.

Sampling. In obtaining soil samples for moisture determinations the improved soil tube was used (10). Samples were taken in one foot increments from the underside of the mulch to bedrock except in the few cases where the soil had a depth greater than 6 ft. A soil tube jack (9) was found indispensable in withdrawing the tubes from the ground. All samples were weighed to the nearest tenth of a gram. It was necessary to dry samples for from 48 to 50 hr at 110-120 deg C to secure constant weight.

Samples for moisture equivalent and permanent wilting percentage determinations were taken in the plots at a one foot offset from the regular sampling locations with a 6-in rotary posthole auger. Approximately 25 lb of soil were secured from each foot depth at each location. We have found no satisfactory method for breaking down samples of these refractory soils to the required degree of fineness except by mechanical means. Accordingly, the samples were air-dried for several weeks and were then run through a small jaw crusher and then through a grinder. The grinder

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[1]Based on data gathered under cooperative agreement between the Bureaus of Agricultural Engineering and Plant Industry, U. S. Department of Agriculture, and the Oregon Agricultural Experiment Station. Prepared under the direction of W. W. McLaughlin, chief, Division of Irrigation, Bureau of Agricultural Engineering, U.S.D.A. Presented for publication as Technical Paper No. 209, with the approval of the Director, as a contribution of the Medford Branch, Oregon Agricultural Experiment Station. Released for first publication in AGRICULTURAL ENGINEERING.

[2]Assistant irrigation engineer, Division of Irrigation, Bureau of Agricultural Engineering, U. S. Department of Agriculture. Assoc. Mem. A.S.A.E.

[3]Irrigation engineer, Oregon Agricultural Experiment Station and Division of Irrigation, Bureau of Agricultural Engineering, U. S. Department of Agriculture. Mem. A.S.A.E.

[4]Figures in parenthesis refer to the list of references which follow this paper.

was kept in uniform adjustment by sieving frequent samples over a 1-mm screen. Retention on the screen of not more than 20 per cent of a sample was allowed.

Moisture Equivalent. A small portion of each sample of soil from the Fitch and Klamath orchards not used for wilting point determination was used for moisture-equivalent determinations in February 1932 by Dr. F. J. Veihmeyer[5] at Davis, Calif. Each moisture equivalent is the result of only one determination for each sample. With certain samples there was some indication of puddling in the centrifuge and the moisture equivalent values for these samples seemed high. Accordingly, sand mixtures were made for these samples and moisture-equivalent determinations were made on the various sand-soil mixtures[6]. The calculated value of the moisture equivalent from each of these mixes is used as the value for samples in which puddling occurred.

All moisture-equivalent determinations on soil from the Medford experiment station plots were made at Pomona, Calif., by C. A. Taylor[7]. The moisture equivalents at the Medford station shown in Table 4 are the result of averaging from two to eight determinations made for each sample.

Field Capacity. Crop-production operations depend on the storage of water in the soil for the use of crops during the periods between rains or irrigation applications. In irrigation practice a knowledge of the quantity of water which may be so stored is essential. Two soil characteristics in particular seem to be involved. These are the ability of the soil to absorb water and its ability to retain the water against gravity. A third factor is the length of time during which the water must be stored. Some soils and crops require irrigation at weekly intervals during the hottest and driest periods. On the other hand, it is common practice in some areas to apply irrigation water in the fall to furnish moisture for early spring crops. Under the latter condition the useful capacity is the quantity which the soil will hold for several months. Under the former condition the water need be held for only a day or two, until the crop has had an opportunity to reduce the supply somewhat.

In practical irrigation work the water-storage capacity is that quantity of water which can be placed in the soil and held there until crops can utilize the available portion of it.

In the orchards under discussion we are dealing with a heavy, very slightly pervious soil of high moisture holding capacity. The apparent specific gravity is high for a clay soil (4). That of the first foot of the Meyer clay adobe soil at the Medford station, is 1.49; of the second foot, 1.48, and of the third foot, 1.57. The determinations were made in the field by the one-foot cylinder method. In the plots receiving frequent irrigation with a relatively high moisture content even before irrigation it would be expected that soil moisture conditions after irrigation would as nearly approach field capacity as in any plot. Soil-moisture conditions in 1932 in the upper 4 ft of the plot designated "frequent" at the Medford station are shown in Fig. 1. Samples were taken in most cases three or four days after

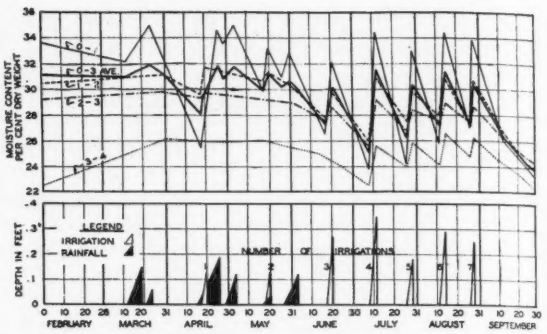

FIG. 1 MOISTURE CONTENT OF EACH OF THE UPPER FOUR FEET AND AVERAGE FOR THE UPPER THREE FEET OF SOIL IN PLOT FREQUENT TOGETHER WITH RAINFALL AND IRRIGATION APPLICATIONS, FEBRUARY TO SEPTEMBER, 1933

irrigation ceased. This was as soon as it was possible to work on the plots without great inconvenience from the sticky mud.

In arriving at an estimate of field capacity on the Medford station plots, three methods were tried. In the "frequent" plot, for instance, the three highest soil-moisture determinations for February 17 to September 2, 1932, for each of the 20 holes in the plot at each depth down to 3 ft were averaged. This gave a value at each depth for each hole. The plot-average percentages by this method were for 0 to 1 ft, 33.53; 1 to 2 ft, 31.74; 2 to 3 ft, 30.74; 0 to 3 ft, 32.00. Fig. 1 shows that at no time in 1932 did the 0 to 3 ft average have a moisture content as high as 32.00 per cent. The highest actual 0 to 3 ft average moisture content recorded was 31.3 per cent for May 1. A moisture content of 31.1 per cent was recorded three times during the season. Evidently this method of averaging the three highest determinations in each hole gave a field capacity that was too high.

The next method used was to average the three highest average determinations for each group of five holes in the plot. By this method the plot-field-capacity percentages were for a depth of 0 to 1 ft, 33.27; 1 to 2 ft, 31.14; 2 to 3 ft, 30.14; 0 to 3 ft, 31.52. Field capacities estimated by this method are lower than those obtained by the first method but are still apparently too high, as indicated by Fig. 1.

The third method used (the one adopted) was the averaging of the three highest average determinations from February 17 to September 2 of each foot depth in each group of ten holes in the east and west halves of the plot. Averaging the east and west groups gives the plot average. By this method the "frequent" plot field-capacity percentages were for a depth 0 to 1 ft, 33.26; 1 to 2 ft, 31.08; 2 to 3 ft, 30.02; 0 to 3 ft, 31.45. These calculated field-capacity percentages check closely with recorded maximum moisture contents of the soil at various depths. This method has been used throughout in estimating field capacities of all plots at the Medford station.

Approximately the same plan was followed in determining field capacities of the Fitch and Klamath plots. In these plots observations covered a period of three years. In 1932, instead of using the average of the three highest determinations of each hole, the value of each field capacity was determined by averaging the six highest plot average soil-moisture determinations obtained in each foot over the three-year period 1930-32, inclusive. In applying this method different dates were used for different depths, as illustrated in Table 1.

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[5]Associate professor of irrigation investigations and practice, College of Agriculture, University of California.

[6]The method is described in a private communication from Dr. Veihmeyer. It consists essentially of determining and plotting the moisture equivalents of four sand-soil mixes in which the sand content varies. Extension of the line plotted through the four points to 100 per cent soil (with no sand) results in a calculated figure for moisture equivalent of the soil alone.

[7]Assistant irrigation engineer, Division of Irrigation, Bureau of Agricultural Engineering, U. S. Department of Agriculture. Mem. A.S.A.E.

TABLE 1. FIELD CAPACITY OF PLOT E, FITCH ORCHARD

Depth ft	Moisture content on various dates in per cent of dry weight						Average field capacity, per cent
	8-5-30	5-28-31	4-29-32	6-17-31	4-20-31	5-31-32	
0–1	25.4	25.3	25.1	24.8	24.7	24.6	24.98
	5-28-31	4-29-32	6-17-31	1-23-32	3-30-32	6-29-31	
1–2	27.0	26.9	26.5	25.9	25.8	25.7	26.30
	6-10-32	2-24-32	5-31-32	5-23-31	6-17-31	7-12-32	
2–3	29.7	29.0	28.7	28.5	28.1	27.8	28.63
0–3	Average						26.64

It is recognized that this method is purely arbitrary but the results secured appear to justify it.

Permanent Wilting Percentage. The permanent-wilting-percentage determinations for the samples from the Fitch and Klamath orchards were made in a greenhouse at Medford during the late summer and fall of 1931. The determinations for samples from five of the holes in the west half of each Medford station plot were made in the summer of 1932 at Medford. The plants for the latter determinations were grown in a canvas-covered lean-to with an open exposure on all sides except the south. Permanent-wilting-percentage determinations from samples from five of the holes in the east half of each Medford station plot were made in the summer and fall of 1932 in a greenhouse at Pomona, Calif., by C. A. Taylor.

The procedure followed at Pomona in 1932, and also at Medford in 1931 and 1932, was essentially the same as that used for some years past at Davis, Calif., by Veihmeyer and Hendrickson (11). The method has been developed by a number of workers. It is believed that the details have not been published and that they are of sufficient interest and value to justify publication. The procedure was as follows:

1. A supply of one-pound baking-powder cans were brought to a tare weight of 110 gm after a hole one-half inch in diameter had been punched in the center of the lid.

2. Eight hundred grams of air-dry soil was provided for each can. A series of eight cans was used for each determination. The sample of soil was poured from the sack into the cans in rotation. All cans were filled a fifth full, and then the soil in each was tamped three times and this procedure was repeated until all the cans contained the quantity provided. Thus the soil in each can was tamped fifteen times, and the content of each was compacted to about the same extent.

3. For each series of eight cans a 100 gm sample of soil was oven-dried and the moisture content of the air-dry soil was determined. Knowing the approximate field capacity of each sample the quantity of water to be added to each can to bring the soil therein to field capacity was computed.

4. The seed was planted in well-manured flats. The seed germinated in about 7 days and each plant had two well-developed leaves in 14 days. When the plants were 4 in high with two to four leaves, they were transplanted to the cans and water was then added. Only healthy, vigorous plants with normal root systems and tops were selected for transplanting. After being transplanted, the plants were guided through the one-half-inch hole in the lid, and the lid was forced into place.

5. The plants were watered frequently until they were 8 or 10 in high with four to eight good leaves. They were then allowed to approach the permanent wilting percentage, when sufficient water was added to raise the soil moisture in the can to approximate field capacity. The hole in the lid around the plant stem was then stuffed with cotton, after which no further water was added.

6. When the plants wilted they were placed in a humidity chamber for 24 hr. A satisfactory chamber large enough to hold 60 plants was made along the lines of a water cooler. Several layers of burlap were tacked over a rigid framework, and the whole was set in a metal drip-pan. Another pan on top of the chamber supplied water through wicks to the walls of the chamber.

7. If the leaves of the plants regained their turgor after 24 hr in the humidity chamber, they were placed in the greenhouse again and the process was repeated until the plants remained wilted in the humidity chamber. When plants remained wilted in the chamber it was considered that the soil moisture in the can had reached the permanent wilting percentage.

8. The can and plant were then weighed, the appropriate deduction for the tare of the can being made. The plant was then cut off at the soil surface and the can and contents were again weighed. Subtraction gave the weight of the top of the plant. The weight of the roots was considered as one-half of the weight of the top of the plant. Eighty per cent of the weight of the roots was considered to be water. Therefore, the weight of the dry roots, dry soil, and soil moisture ("moist weight" for the purpose of computation) was assumed to be the weight of the moist soil and roots, less 40 per cent of the weight of the plant top.

9. The cans were then placed in the oven and the soil dried for 48 to 54 hr at 110 to 120 deg C.

10. The weight at reweighing was that of the oven-dry soil and dry roots. The difference between the moist weight (No. 8 above) and the weight after drying was the soil moisture. This difference divided by the dry weight, less the dry weight of the roots, (10 per cent of the top weight) times 100 gave the per cent of moisture present in the soil when the plant wilted. The average of the eight samples in the series was used as the value of the permanent wilting percentage for that particular sample.

Several lots of sunflower seed were tried in these experiments. The most satisfactory variety (the one that has been used in all subsequent permanent wilting percentage work) was the Siberian dwarf sunflower secured from the University of Saskatchewan.

In many cases it was difficult for seeds to establish themselves in this heavy soil with moisture equivalents of over 40 per cent.

The transplanting method overcame the difficulty experienced in the early work at Medford when sunflower seeds were planted directly in the cans. The method used in the studies proved very satisfactory and is recommended for use with heavy clay soils. Plants with greater vigor and of greater uniformity were secured and about a month was saved.

At Medford baking-powder cans have been used for plant containers with the advantage that the hard-baked soil can be easily removed by jarring and the can salvaged for further use. In 1931 the same cans were used for three consecutive series of determinations.

Data. Values of the moisture equivalent, field capacity, and permanent wilting percentage, with probable errors, and ratios of the moisture equivalent to the permanent wilting percentage, field capacity to moisture equivalent, and field capacity to permanent wilting percentage, for each foot to 3 ft in depth for each plot in the Fitch orchard are shown in Table 2. Tables 3 and 4 show similar data for the Klamath and Medford station plots, respectively. On the deeper Medford station plots moisture equivalents and permanent wilting percentages are shown to depths of 5 or 6 ft.

TABLE 2. COMPARISON OF MOISTURE EQUIVALENT, FIELD CAPACITY, PERMANENT WILTING PERCENTAGE, AND THEIR RATIOS, AT DEPTHS FROM 0 TO 3 FT IN FOUR ADJACENT PLOTS ON MEYER SILTY CLAY LOAM SOIL

FITCH ORCHARD

Plot	Depth, ft	M. E.	F. C.	P. W. P.	M.E. / P.W.P.	F.C. / M.E.	F.C. / P.W.P.
E	0–1	27.26 ± 0.79	24.98 ± 0.09	13.8 ± 0.20	1.97	0.92	1.81
	1–2	29.56 ± .37	26.30 ± .16	14.7 ± .17	2.01	.89	1.79
	2–3	36.01 ± 1.83	28.63 ± .18	17.1 ± .40	2.10	.80	1.67
	0–3	30.94 ± .68	26.64 ± .09	15.2 ± .16	2.03	.86	1.75
D	0–1	25.56 ± .29	25.25 ± .23	12.9 ± .20	1.98	.99	1.96
	1–2	34.63 ± .97	27.15 ± .15	15.7 ± .23	2.20	.78	1.73
	2–3	35.19 ± .90	28.17 ± .21	17.2 ± .30	2.04	.80	1.64
	0–3	31.79 ± .45	26.86 ± .12	15.3 ± .14	2.08	.85	1.75
B	0–1	27.60 ± .54	24.83 ± .14	13.2 ± .19	2.09	.90	1.88
	1–2	35.46 ± .32	28.57 ± .14	16.3 ± .16	2.17	.81	1.75
	2–3	35.28 ± 1.28	27.52 ± .24	17.5 ± .21	2.02	.78	1.57
	0–3	32.78 ± .47	26.97 ± .10	15.7 ± .11	2.09	.82	1.72
C	0–1	26.07 ± .25	23.80 ± .20	13.3 ± .20	1.96	.91	1.79
	1–2	30.83 ± .29	27.52 ± .14	15.9 ± .18	1.94	.89	1.73
	2–3	37.63 ± .36	29.57 ± .12	17.8 ± .21	2.11	.79	1.66
	0–3	31.51 ± .17	26.96 ± .09	15.7 ± .11	2.01	.86	1.72
Average of all plots	0–3	31.75 ± .24	26.86 ± .05	15.5 ± .07	2.05	.85	1.73

NOTE: Each moisture equivalent (M.E.) value in the table is the average of five determinations; each field capacity (F.C.) value of six determinations; each permanent wilting percentage (P.W.P.) value of thirty to forty determinations. Soil samples were ground before making the laboratory determinations.

Table 5 is a summary of the 0 to 3 ft averages of all plots in the three orchards.

Ratio of Moisture Equivalent to Permanent Wilting Percentage. The ratio of moisture equivalent to permanent wilting percentage was formerly considered to be uniform for all soils. Briggs and Shantz (1) concluded that the wilting coefficient could be obtained for any soil by dividing the moisture equivalent by 1.84. Veihmeyer and Hendrickson (11) have shown that no common factor can be used to calculate the moisture present in all soils at permanent wilting from the moisture equivalent. Data reported in this paper indicate that the ratio of moisture equivalent to permanent wilting percentage varies within a single soil type. The soils of both the Klamath and Medford station orchards are classified (7) as Meyer clay adobe and from casual observation appear to be very similar in texture and structure, yet the ratio of moisture equivalent to permanent wilting percentage on the Klamath plots averages 2.03 in the 0 to 3-ft depths for all four plots, while the 0 to 3-ft average of the Medford station plots is 2.27. The data show the moisture equivalent to range from 2.14 to 2.46 times the permanent wilting percentage in the upper 3-ft average of adjoining half plots, the mean of the areas of which is 0.44 acre.

The data reported in this paper show that on the plots and soils studied the ratio of moisture equivalent to perma-

TABLE 3. COMPARISON OF MOISTURE EQUIVALENT, FIELD CAPACITY, PERMANENT WILTING PERCENTAGE, AND THEIR RATIOS, AT DEPTHS OF 0 TO 3 FT IN FOUR ADJOINING PLOTS ON MEYER CLAY ADOBE SOIL

KLAMATH ORCHARD

Plot	Depth, ft	M. E.	F. C.	P. W. P.	M.E. / P.W.P.	F.C. / M.E.	F.C. / P.W.P.
E	0–1	30.87 ± 0.82	29.73 ± 0.14	16.0 ± 0.23	1.93	0.96	1.86
	1–2	34.28 ± .88	28.66 ± .04	17.0 ± .25	2.02	.84	1.68
	2–3	35.93 ± .40	27.45 ± .12	16.9 ± .17	2.13	.76	1.62
	0–3	33.69 ± .42	28.62 ± .06	16.6 ± .12	2.03	.85	1.72
D	0–1	32.88 ± .59	29.93 ± .19	16.8 ± .22	1.96	.91	1.78
	1–2	34.83 ± .42	27.98 ± .06	17.1 ± .19	2.04	.80	1.64
	2–3	34.48 ± .66	26.65 ± .26	18.0 ± .27	1.92	.77	1.48
	0–3	34.06 ± .33	28.19 ± .11	17.3 ± .13	1.97	.83	1.63
B	0–1	31.96 ± .81	27.02 ± .24	15.6 ± .23	2.05	.85	1.73
	1–2	31.21 ± .46	27.13 ± .13	17.7 ± .19	1.93	.79	1.53
	2–3	31.83 ± .91	26.10 ± .13	15.3 ± .28	2.08	.82	1.70
	0–3	32.67 ± .43	26.75 ± .10	16.2 ± .14	2.02	.82	1.65
C	0–1	31.67 ± .59	28.15 ± .27	14.7 ± .10	2.15	.89	1.91
	1–2	35.70 ± .23	28.25 ± .09	16.9 ± .25	2.11	.79	1.67
	2–3	35.11 ± .48	29.02 ± .11	16.6 ± .20	2.11	.83	1.75
	0–3	34.16 ± .26	28.47 ± .11	16.1 ± .11	2.12	.83	1.77
Average of all plots	0–3	33.65 ± .18	28.01 ± .05	16.6 ± .06	2.03	.83	1.69

NOTE: Each moisture equivalent (M.E.) value in the table is the average of five determinations; each field capacity (F.C.) value of six determinations; each permanent wilting percentage (P.W.P.) value of thirty to forty determinations. Soil samples were ground before making the laboratory determinations.

nent wilting percentage generally increases slightly with depth down to depths of 3 or 4 ft.

Relation of Field Capacity to Moisture Equivalent. The data on the ratio of field capacity to moisture equivalent are shown graphically on Fig. 2. The ratios for each of the upper 3 ft of soil and for each plot in each orchard are plotted against the corresponding moisture equivalent. In each case the average of the four plots in each orchard also has been plotted.

It is evident that the ratio definitely decreases as the depth of sampling increases. In the upper foot the ratio does not change with a change in moisture equivalent, while in the second and third feet there is a tendency for the ratio to decrease with an increase in the moisture equivalent. The coefficients of correlation between the ratio F.C./M.E. and the moisture equivalent are 0.0, —0.57, and —0.75 for the first, second, and third foot, respectively.

If the data for the different orchards are considered separately, there is found a definite tendency for the ratio to decrease both with increasing depth and with increasing moisture equivalent. The coefficients of correlation between the F.C./M.E. ratio and the moisture equivalent are —0.93, —0.74, and —0.55 for the Fitch, Klamath, and Medford station orchards, respectively. If all the data are considered in a single group there is a correlation of —0.59 between the F.C./M.E. ratio and the moisture equivalent.

TABLE 4. COMPARISON OF MOISTURE EQUIVALENT, FIELD CAPACITY, PERMANENT WILTING PERCENTAGE, AND THEIR RATIOS AT DEPTHS FROM 0 TO 6 FT IN ADJOINING HALF PLOTS ON MEYER CLAY ADOBE SOIL

MEDFORD STATION

Plot	Depth, ft	M. E.	F. C.	P. W. P.	M.E. / P.W.P.	F.C. / M.E.	F.C. / P.W.P.
Frequent west	0–1	36.24 ± 0.12	33.5 ± 0.35	15.9 ± 0.19	2.28	0.92	2.11
	1–2	42.38 ± .26	30.9 ± .13	17.1 ± .22	2.48	.73	1.81
	2–3	45.65 ± .31	30.1 ± .12	17.4 ± .23	2.62	.66	1.73
	3–4	40.13 ± .17		16.7 ± .22	2.40		
	4–5	33.45 ± .05		14.1 ± .16	2.37		
	5–6	30.78 ± .08		14.0 ± .27	2.20		
	0–3	41.42 ± .14	31.5 ± .13	16.8 ± .12	2.46	.76	1.87
Frequent east	0–1	38.34 ± .19	33.0 ± .21	17.2 ± .12	2.23	.86	1.92
	1–2	38.02 ± .12	31.2 ± .05	17.3 ± .09	2.20	.82	1.80
	2–3	40.26 ± .25	30.0 ± .05	18.0 ± .12	2.24	.75	1.37
	3–4	33.83 ± .09		16.2 ± .18	2.09		
	4–5	30.15 ± .11		14.4 ± .19	2.09		
	0–3	38.87 ± .11	31.4 ± .07	17.5 ± .06	2.22	.81	1.79
One irrigation west	0–1	39.18 ± .32	36.3 ± .10	17.7 ± .12	2.21	.93	2.05
	1–2	40.70 ± .30	33.0 ± .23	17.6 ± .15	2.31	.81	1.88
	2–3	39.74 ± .22	31.0 ± .46	17.4 ± .18	2.28	.78	1.78
	3–4	38.31 ± .07		16.4 ± .22	2.33		
	0–3	39.88 ± .16	33.4 ± .17	17.6 ± .09	2.26	.84	1.90
One irrigation east	0–1	38.24 ± .05	36.3 ± .18	18.2 ± .11	2.10	.95	1.99
	1–2	39.94 ± .24	33.1 ± .39	18.7 ± .15	2.13	.83	1.77
	2–3	42.60 ± .47	31.8 ± 43	19.4 ± .22	2.19	.75	1.64
	3–4	37.77 ± .27		17.6 ± .16	2.15		
	0–3	40.26 ± .18	33.7 ± .20	18.8 ± .09	2.14	.84	1.79
Frequent early west	0–1	37.82 ± .19	33.0 ± .13	16.9 ± .13	2.24	.87	1.95
	1–2	38.33 ± .28	31.2 ± .27	16.6 ± .18	2.31	.81	1.88
	2–3	37.50 ± .22	29.7 ± .34	16.5 ± .13	2.27	.79	1.80
	3–4	33.93 ± .17		15.7 ± .29	2.16		
	0–3	37.88 ± .13	31.3 ± .11	16.7 ± .09	2.27	.83	1.87
Frequent early east	0–1	35.83 ± .15	31.9 ± .32	16.5 ± .07	2.17	.89	1.93
	1–2	36.72 ± .15	30.3 ± .10	16.7 ± .07	2.20	.83	1.81
	2–3	35.00 ± .07	26.5 ± .13	16.4 ± .11	2.13	.76	1.61
	0–3	35.85 ± .07	29.6 ± .12	16.5 ± .05	2.17	.83	1.79
Frequent late west	0–1	38.69 ± .18	36.7 ± .38	17.6 ± .17	2.20	.95	2.08
	1–2	42.17 ± .31	33.8 ± .18	17.6 ± .20	2.40	.80	1.92
	2–3	44.35 ± .36	32.3 ± .12	17.5 ± .24	2.53	.73	1.84
	3–4	39.71 ± .39		16.4 ± .36	2.42		
	4–5	30.37 ± .07		14.1 ± .19	2.15		
	5–6	34.92 ± .29					
	0–3	41.74 ± .17	34.3 ± .14	17.6 ± .12	2.37	.82	1.95
Frequent late east	0–1	37.13 ± .04	35.5 ± .18	17.3 ± .08	2.15	.96	2.05
	1–2	41.97 ± .41	32.5 ± .23	18.2 ± .14	2.31	.77	1.78
	2–3	40.86 ± .15	31.0 ± .23	18.5 ± .15	2.21	.76	1.67
	3–4	34.99 ± .08		16.3 ± .09	2.15		
	4–5	33.51 ± .27		14.5 ± .10	2.31		
	5–6	29.51 ± .06		13.9 ± .14	2.12		
	0–3	39.99 ± .15	33.0 ± .12	18.0 ± .07	2.22	.82	1.83
Average of all plots	0–3	39.48 ± .05	32.3 ± .05	17.4 ± .03	2.27	.82	1.86

NOTE: Each moisture equivalent (M.E.) value in the table is the average of ten to twenty determinations; each field capacity (F.C.) value of thirty soil moisture determinations; and each permanent wilting percentage (P.W.P.) value of thirty to forty determinations. Permanent wilting percentage determinations on the east half of each plot were made at Pomona, Calif., and permanent wilting percentage determinations on the west half of each plot were made at Medford, Ore. Soil samples were ground before making the laboratory determinations.

The ratio of field capacity to moisture equivalent, expressed decimally, corresponds with Veihmeyer and Hendrickson's (12) "relative wetness" of soil at field capacity. For the heavy Medford soils this ratio is lower than any "relative wetness" of the various clays, clay adobes, loams, silt loams, and sandy soils reported by those investigators (13). Burr and Russel (2), working with fine-textured soils, have reported the field capacity of the upper 6 ft as 0.91 times the moisture equivalent. These investigators, working on soils with moisture equivalents of 23 to 30, found that the F.C./M.E. ratio decreased in magnitude with depths down to 3 ft in each of six reported tests.

Israelsen (3), working with fine-textured soils of high volume weight, found the F.C./M.E. ratio to range from 0.67 to 0.83. He found that the ratio apparently decreased with depth on heavy clay soils of slight permeability. Israelsen, however, thought that this low ratio might be due to difficulty in getting the soils fully wetted. He also suspected that some changes in the apparent specific gravity of samples centrifuged for moisture equivalent in comparison with the apparent specific gravity of undisturbed soil may have occurred.

Piper (5) summarizes the work of these and other investigators of the relation of field capacity, specific retention, and moisture equivalent, and shows the results on a graph similar to Fig. 2. If the line representing the ratio for all the data considered as a single group on Fig. 2 is superimposed on his graph, it is found that it agrees very well both with the curve showing the results of Piper's own investigations and with the combined data of the other investigators referred to. Veihmeyer, Oserkowsky, and Tester (13) point out that preparation of soil samples for moisture-equivalent determination by grinding may make a decided difference in the results as compared with results obtained by preparing samples by other means. That an increase in the moisture equivalent in these studies resulted from the milling of the samples is probable. If this did result the F.C./M.E. ratio would be decreased and could not be directly comparable with Veihmeyer and Hendrickson's "relative wetness."

In fifteen out of sixteen plots the F.C./M.E. ratio decreased in magnitude in the second foot in comparison with that of the first foot, and in thirteen out of sixteen plots the ratio decreased in magnitude in the third foot in comparison with that of the second foot. In other words, with

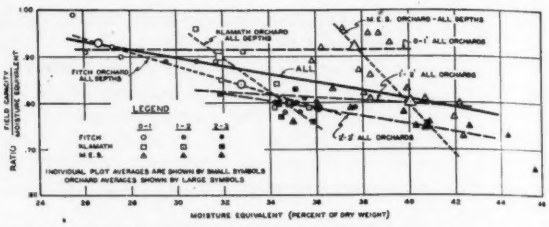

FIG. 2 RATIO OF FIELD CAPACITY OF MOISTURE EQUIVALENT AS RELATED TO MOISTURE EQUIVALENT FOR EACH OF THE UPPER 3 FEET OF SOIL IN EACH PLOT IN THE FITCH, KLAMATH, AND MEDFORD STATION ORCHARDS

increased depth the moisture equivalent becomes relatively greater than the field capacity. In fact, at the Medford station field capacity decreases with depth, while moisture equivalent generally increases with depths down to 3 ft. Similar conditions are observed in three of four plots in the Klamath orchard, but at the Fitch orchard both moisture equivalent and field capacity increased with depth. These data clearly show that any F.C./M.E. ratio derived for the first foot cannot be applied to soils at lower levels.

It seems probable that the relatively lower field capacity of the subsoil is due, at least in part, to the high apparent specific gravity of the soil. Assuming that the real specific gravity of the soil is 2.65, the pore space in the Medford orchard soil would be 43.8, 44.2, and 40.8 per cent in the first, second, and third foot, respectively, and when this pore space is filled the weights of the water content would be 29.4, 29.9, and 26.0 per cent of the dry weight of the soil, respectively.

The data clearly indicate that where the 0 to 3-ft zone is considered as a unit, the F.C./M.E. ratio is very uniform in adjoining plots (Table 5) and is uniform even between differing types of heavy soil. (For silty clay loam, 0.85; clay adobe (Klamath plots), 0.83; clay adobe (Medford station), 0.82). The variation between soils of the three orchards is no greater than the variation between adjoining plots in the same orchard.

Relation of Field Capacity to Permanent Wilting Percentage. In the soils investigated at Medford the field capacity for individual plots and foot-depths ranged from 1.48 to 2.11 times the permanent wilting percentage and for the 0 to 3-ft plot averages from 1.63 to 1.95 times the

TABLE 5. SUMMARY OF MOISTURE EQUIVALENTS, FIELD CAPACITIES, PERMANENT WILTING PERCENTAGES, AND THEIR RATIOS, FOR THE 0 TO 3-FT DEPTH OF HEAVY SOILS AT MEDFORD, OREGON

Orchard	Plot	M. E.	F. C.	P. W. P.	M.E. / P.W.P.	F.C. / M.E.	F.C. / P.W.P.
Fitch	E	30.94 ± 0.68	26.64 ± 0.09	15.2 ± 0.16	2.03	0.86	1.75
	D	31.79 ± .45	26.86 ± .12	15.3 ± .14	2.08	.85	1.75
	B	32.78 ± .47	26.97 ± .10	15.7 ± .11	2.09	.82	1.72
	C	31.51 ± .17	26.96 ± .09	15.7 ± .11	2.01	.86	1.72
	Average	31.75 ± .24	26.86 ± .05	15.5 ± .07	2.05	.85	1.73
Klamath	E	33.69 ± .42	28.62 ± .06	16.6 ± .12	2.03	.85	1.72
	D	34.06 ± .33	28.19 ± .11	17.3 ± .13	1.97	.83	1.63
	B	32.67 ± .43	26.75 ± .10	16.2 ± .14	2.02	.82	1.65
	C	34.16 ± .23	28.47 ± .11	16.1 ± .11	2.12	.83	1.77
	Average	33.65 ± .18	28.01 ± .05	16.6 ± .06	2.03	.83	1.69
Medford Station							
Frequent W.		41.42 ± .14	31.50 ± .13	16.8 ± .12	2.46	.76	1.87
Frequent E.		38.87 ± .11	31.40 ± .07	17.5 ± .06	2.22	.81	1.79
One irrig. W.		39.88 ± .16	33.40 ± .17	17.6 ± .09	2.26	.84	1.90
One irrig. E.		40.26 ± .18	33.70 ± .20	18.8 ± .09	2.14	.84	1.79
Freq. early W.		37.88 ± .13	31.30 ± .11	16.7 ± .09	2.27	.83	1.87
Freq. early E.		35.85 ± .07	29.60 ± .12	16.5 ± .05	2.17	.83	1.79
Freq. late W.		41.74 ± .17	34.30 ± .14	17.6 ± .12	2.37	.82	1.95
Freq. late E.		39.99 ± .15	33.00 ± .12	18.0 ± .07	2.22	.83	1.83
	Average	39.48 ± .05	32.30 ± .05	17.4 ± .03	2.27	.82	1.86

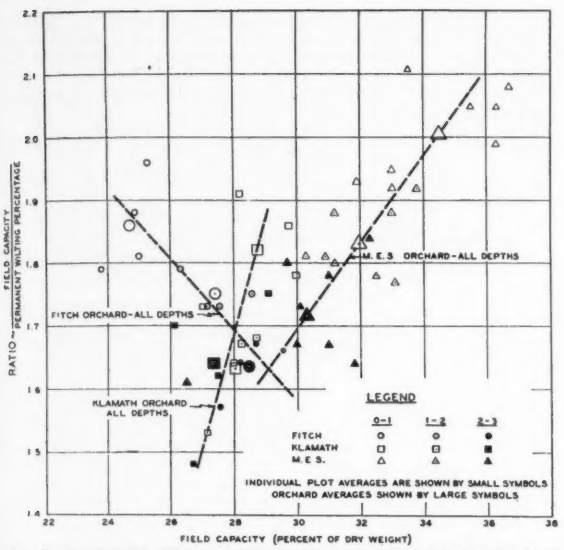
RATIO — FIELD CAPACITY / PERMANENT WILTING PERCENTAGE
FIELD CAPACITY (PERCENT OF DRY WEIGHT)
M. E. S. ORCHARD - ALL DEPTHS
FITCH ORCHARD - ALL DEPTHS
KLAMATH ORCHARD ALL DEPTHS
LEGEND
0-1 1-2 2-3
FITCH
KLAMATH
M. E. S.
INDIVIDUAL PLOT AVERAGES ARE SHOWN BY SMALL SYMBOLS
ORCHARD AVERAGES SHOWN BY LARGE SYMBOLS

FIG. 3 RATIO OF FIELD CAPACITY TO THE PERMANENT WILTING PERCENTAGE AS RELATED TO FIELD CAPACITY FOR EACH OF THE UPPER 3 FEET OF SOIL IN EACH PLOT IN THE FITCH, KLAMATH, AND MEDFORD STATION ORCHARDS

permanent wilting percentage. The data plotted on Fig. 3 show that in each orchard the ratio decreased with depth. In the Fitch orchard the F.C./P.W.P. ratio decreased with increasing field capacity, but in the other two orchards the ratio increased as the field capacity increased. The data indicate that where the 0 to 3-ft zone is considered as a unit (the field capacity being known), the permanent wilting percentage can be estimated fairly closely for the heavy soils studied by dividing the field capacity by the factor 1.76.

Determination of field capacity by the method described in this paper is a relatively simple matter, requiring only that care be used in the selection of time of sampling after irrigation and that a sufficient number of samples be taken over a long enough period of time to insure accurate representation of soil moisture conditions in the field, subsequent to irrigation or prolonged precipitation.

In the case of the Medford station soil the differences between plots of moisture equivalent, field capacity, and permanent wilting percentage for the 0 to 3-ft average are statistically significant in more cases than otherwise.

Table 5 shows that at the Medford station the moisture equivalents and field capacities of each east half of plots "frequent," "frequent early" and "frequent late," are significantly lower than those of the corresponding west half. This is not true of the permanent wilting percentages. In every case the M.E./P.W.P. and F.C./P.W.P. ratios are numerically lower in the east half of each plot than in the west half. The F.C./M.E. ratios, however, are exactly the same in two of the four plots and almost the same in the other two. It is possible that either a difference in technique or a difference between growing conditions in Pomona, Calif. (latitude 34 deg), and in Medford, Ore. (latitude 42 deg 30 min), is responsible for the apparent difference in permanent wilting percentages. The west-half percentages (determined at Medford) appear to be relatively too low and the east-half percentages (determined at Pomona) appear relatively too high.

The field F.C./P.W.P. ratio in all three orchards, on both types of soil, appears to be more uniform than the M.E./P.W.P. ratio.

Briggs and Shantz (1) proposed the following formula for estimating the wilting coefficient from the mechanical analysis of the soil:

$$\text{Wilting Coefficient} = \frac{0.01\ \text{sand} + 0.12\ \text{silt} + 0.57\ \text{clay}}{1 \pm 0.025}$$

According to this formula and the mechanical analyses given above, the A horizon of the Meyer silty clay loam should have a wilting coefficient of 19.8, and the B horizon should have one of 19.9 as compared with average values for the permanent wilting percentage as determined in this study of 13.3, 15.6, and 17.4 in the first, second, and third feet, respectively. By the use of the same formula and the analysis of a typical sample of the Meyer clay adobe, a wilting coefficient of 33.0 per cent is found, while the analysis by Stephenson gives a value of 25.1 per cent. The permanent wilting percentage averaged 17.0 per cent for the upper 3 ft in this study. Perhaps both the very low water-holding capacity, as compared with the soil texture, and the low F.C./M.E. ratio are related to the high apparent specific gravities of these soils.

SUMMARY AND CONCLUSIONS

In soils that appear uniform in structure and texture differences may exist that are not readily discernible in casual examination. Study of soil moisture constants at increasing depths below the soil surface will interpret these differences in terms of maximum available moisture. With the soils studied at Medford the maximum available moisture content generally decreased with depth.

With these Medford soils moisture equivalent generally increases with depths to 3 ft, but on the Klamath and Medford station soils (Meyer clay adobe) field capacity usually decreases with depth. In the Medford soils the moisture equivalent is not equal to field capacity. In the 0 to 3-ft average of the three orchards, for two heavy soil types field capacity equaled only 0.83 of the moisture equivalent. Determinations show the permanent wilting percentage to increase with depth with Meyer silty clay loam, but to remain about the same or with a slight tendency to increase with depth, at depths from 0 to 3 ft with Meyer clay adobe soil.

Our data show that an M.E./P.W.P. ratio derived for any particular depth of soil cannot be applied exactly to any other horizon. The ratios for the averages of all plots and half plots in the three orchards are for the first foot, 2.10; for 1 to 2 ft, 2.17; and for 2 to 3 ft, 2.19.

Our results show that a F.C./P.W.P. ratio derived for any one soil level cannot accurately be applied to any other soil level. The ratios for the averages of all plots and half plots in the three orchards are for the depths 0 to 1 ft, 1.93; 1 to 2 ft, 1.76; and 2 to 3 ft, 1.68. The F.C./P.W.P. ratio decreases with depth, but the M.E./P.W.P. ratio increases with depth.

In general, for the 0 to 3-ft average, the data show that the F.C./P.W.P. ratio is less subject to variation from a mean in adjoining plots, or in plots not adjoining but on similar soil types, than the M.E./P.W.P. ratio. For instance, if we use the M.E./P.W.P. ratio of 2.12 for the sixteen plots and half plots on two soil types in three orchards to calculate the 0 to 3-ft average permanent wilting percentage from the corresponding moisture equivalents for the sixteen plots and half plots, we shall have a mean deviation of 0.89 per cent from the mean observed permanent wilting percentage, but if we use the average F.C./P.W.P. ratio of 1.76, we shall have a deviation of 0.57 per cent. This difference, while not important, is indicative of the greater accuracy of the F.C./P.W.P. ratio over the M.E./P.W.P. ratio.

The data indicate that, with the soils studied, for practical orchard operation, in which it is important to know the approximate field capacity and available moisture capacity of the soil in the major portion of the root zone, the field capacity may be readily determined and the permanent wilting percentage for the 0 to 3-ft average may be approximated by dividing field capacity by the factor 1.76. If for any particular reason greater accuracy is desired, the ratio found for each foot of depth should be used.

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Progress in Farm Electrification as Gleaned from an Agricultural Engineers Meeting

By L. J. Smith

AS IS THE CUSTOM, a technical program of the farm electrification specialists was presented in connection with the 28th annual meeting of the American Society of Agricultural Engineers at Detroit, Michigan, June 18, 19, and 20. During the early development of the field of farm electrification, this group held separate meetings at the same time and placed the ASAE annual meeting, and it may said that the Society has always extended its fullest support to the farm electric work. Now, however, farm electrification is recognized as one of the four main branches of agricultural engineering, and as such is given a place equal to other technical groups in Society activities.

The first number on the rural electric program ("Electric Lighting and Its Application to Rural Areas," by W. C. Brown, illuminating engineer, General Electric Company) was one of the most interesting and instructive of the whole program. It was a combination of a report of the Committee on Lighting of the Society and a general symposium of the field of rural lighting. Insect control, irradiation of poultry, animals, and humans, the growing of house plants, and light for growth were among the topics briefly discussed. Among the displays, that of "Plant Lites," a combination of light stands and plant stands, drew universal attention. This innovation opens a new field for further use of light in the living rooms of the home.

In this presentation the use of the light meter was stressed. Several good types of floor and student lamps were shown. It was felt that the electric light would eventually be of value in combination with other machines for insect control. The future greater use of ultra-violet light and infra-red lamps for health in the home, the poultry house, and the barn was stressed. One could not listen to this valuable exposition of the future use of light in agriculture without feeling that the electric load for light use on the farm is due to increase steadily.

The second number was an informal talk by J. H. Flessner, rural service engineer, Detroit Edison Company, entitled "Experiences in Developing Farm Electrification." Mr. Flessner told in a very interesting way of the early developments and present accomplishments of his organization in the field of farm electrification. Starting in the winter of 1927, the company now has six full-time rural electric engineers in the field. In one of the counties in their territory, ninety per cent of the farms are connected. The speaker said that the cooperation of the electrical equipment dealers was none too good, that there was a need to work out this problem with the dealers who were not very active out in the country. His company builds lines for $1000 per mile, down to $750. They are setting poles around 100 ft back from the highway in the fields to eliminate trouble from the trees. Many of the highways in this old settled country have large trees, which has given a good deal of difficulty in connection with rural lines construction and upkeep. Mr. Flessner stated it usually was not difficult to get the consent of the farmers to the above-mentioned location of poles when the line extension was being arranged for. Usually a prominent farmer interested in the extension made the arrangements. He also stated that while the load had dropped somewhat, payments were good and the company looked forward with confidence to a satisfactory future development of farm electrification in eastern Michigan.

Miss Gail M. Redfield, research assistant in home economics, Purdue University, presented an excellent paper on electric equipment in the farm home. The paper contains much interesting information from the woman's viewpoint. Miss Redfield called the household load a labor-saving load, releasing time for leisure, self-improvement, and planning. She stressed the value of automatic control and stated that farm women need more reliable information from electric-equipment companies. She felt that everything possible must be done to avoid unpleasant experiences in connection with the use of new equipment, since it would naturally hurt the development of the use of electricity in the homes in that particular neighborhood. She felt also that women need more knowledge of electrical terms in order to give them a proper background for the purchase and use of electrical equipment. Miss Redfield gave a good deal of data on uses of home electrical equipment. The Purdue University studies on the time required to care for cooking equipment were very interesting. The electric range required 26 min a week; wood and coal ranges averaged 3 hr and 2 min a week, of twenty 8-hr days per year. Miss Redfield felt that the electric range was of real value to farm women and would eventually become part of the farm home equipment. She also said that farm homes need larger refrigeration than urban homes. She closed with the thought that electricity eliminates drudgery in the home.

Dr. Louise Stanley, chief, Bureau of Home Economics, U. S. Department of Agriculture, who was present for this afternoon session, was called upon to discuss the paper. Dr. Stanley was greatly interested in the use of electricity in the farm home. She felt that electricity could be of great service to farm women. In connection with electric cooking, she was sure that it would be necessary to really teach electric cooking, if it is to be used to any great extent on the farm. There was a great need also of dish-

washing equipment that would not be too expensive. Dr. Stanley said that here was a real opportunity to eliminate drudgery, for dishes had to be washed three times a day and at a time when no one felt like washing them. Dr. Stanley felt that in the coming farm-home-remodeling movement, adequate wiring and electrical equipment were most important. Mrs. E. R. Meacham was called on and stressed the need of more publicity in connection with new developments concerning the uses of electricity in the home. She felt that proper news articles and publicity could do a great deal in popularizing studies and data coming from colleges and experiment stations, much of which was apt to be too technical.

H. J. Gallagher, farm electric specialist, Michigan State College, gave a talk on electric equipment for irrigation, which covered largely Michigan conditions. He thought that wherever possible use should be made of simple, inexpensive equipment at least at the beginning rather than going into irrigation on too large a scale. First, he said, prove the value of irrigation and then the larger developments will come. Mr. Gallagher gave parts of the report of the Committee on Irrigation. He told of the Michigan forestry method of putting down shallow wells. His description, however, was rather brief.

H. H. Musselman, head of the department of agricultural engineering, Michigan State College, in commenting on Mr. Gallagher's remarks, felt that while there are quite a number of rivers and small streams from which water could be had for irrigation purposes, yet there was a very considerable possible development of irrigation in Michigan from shallow wells which should not be neglected.

This particular meeting lasted until after five o'clock, considerable discussion of developing the electric load and particularly the cooking load coming at the end of the papers. Several told of difficulties they had had in connection with the development of the electric load in the home. There was a general feeling that the electric load in the home will not just grow like Topsy, but that it must be intelligently but conservatively promoted and then carefully followed up. Getting an electric range into the average home is only the beginning. If real progress in the electrification of the farm home is to be made, there must be definite follow-up programs. From the discussion it was apparent that many mistakes had been made in the development of uses of electricity in agriculture, but it was felt that a study of those errors would be of great value in preventing their repetition.

At the next session of the Rural Electric Division, J. P. Schaenzer, agricultural and irrigation engineer of the National Power Survey (Federal Power Commission), told of his work in endeavoring to compile data in regard to the future uses of electricity in agriculture. He gave the object of the power survey as (1) procuring information concerning power resources; (2) markets for power, including industry, domestic, commercial, railroads, and rural; (3) future uses and possibilities; (4) a study of non-users of electric power. Concerning Mr. Schaenzer's work in connection with the rural phase, he stated that he would proceed by securing all possible data from all available sources for compilation and study and asked the hearty cooperation of all those interested in farm electrification work.

George W. Kable told of the rural electric survey which was a phase of the federal farm housing survey. He hoped that the work, which was cut off so unexpectedly by the shifting of relief funds, might be continued to completion. Mr. Kable stated that such was the case in a number of states. He felt that the data secured would result in making available a greater amount of knowledge in regard to farm electrification in the United States. He thought that it might in some cases constitute a basis for a public works program or relief measures. As an example, in North Carolina Mr. Weaver surveyed three counties and then built two rural lines with CWA funds for further study. In one county, relief labor cut over three times as many poles as was needed for their line construction. The additional poles were traded or sold for other line materials. Mr. Kable hoped that in some localities PWA funds might be used in rural electric development programs.

R. W. Trullinger, senior agricultural engineer, Office of the Experiment Stations, U. S. Department of Agriculture, gave a brief talk concerning possible farm electrification on federal reclamation projects. He felt that it was difficult to tell what part electricity may have in some of these developments, some of which would of necessity be concerned with large acreages per farm. He thought that the agricultural engineering group should withhold judgment concerning these developments but be ready to be of any possible assistance when needed.

G. W. McCuen, the incoming president of the Society, said that electricity will do more for agriculture and the farm home than any other development of the past generation.

Arthur Huntington, outgoing president of the Society, closed the session with an account of some of the early history of rural electrification in Iowa, at which time very little was done to assist the farmer and his wife in their use of electricity. Many of these early attempts were not successful. He stated that the American Society of Agricultural Engineers has been very active in sponsoring studies in farm electrification and has secured a lot of basic data. He felt that the agricultural engineers should study all factors in connection with the farm electrification problem and try to determine how each factor would affect each individual situation, even though some of them might be outside of the field of agriculture. Mr. Huntington said that there is considerable data assembled but that much of it has not been put in good form and analyzed so as to be of value. This, he thought, should be done at once. He felt also that it was possible to have development proceed too fast, that it would often be much better to proceed more slowly. He stressed the need of studying our failures in connection with our attempts to develop economic uses of electricity on the farm and in the farm home.

The session closed with the feeling that a very profitable time had been spent and that farm electrification was perhaps moving ahead slowly, but on a better and broader foundation which would be of distinct value as times improved.

At the next session of the Rural Electric Division, F. B. Wright, assistant professor of agricultural engineering, Cornell University, told of rural electric courses for high school teachers. Their courses have developed a great deal of interest in the teaching in the schools of the applications of electricity to agriculture.

The report of the Committee on Soil Heating was presented by the writer, in the absence of the chairman, H. L. Garver.

George A. Rietz, in charge of rural electrification activity for the General Electric Company, gave a talk on research and new applications in farm electrification. He stated that electricity will find many new uses on farms; that it will do a great deal toward eliminating noise and odors; that it is cleaner and competes with gas and oil in cooking; that it has greater flexibility and better control. He felt that the extension of electricity in agriculture depends considerably on larger volumes which produce lower rates; and that the lower cost of extensions was another very important item. He stressed the need of a study of small electric tractors. He stated that electrical energy is universal in its application, and that the General Electric Company employed five hundred power research men, allowing them to work in almost any field in which electricity was used. One can never tell when their findings will have application to agriculture or to industry. The company has a strong engineering development group whose business it is to take new knowledge and mold it into usable form for practical life. Mr. Rietz felt that there was a real future in light uses, such as plant growth, insect control, ultra-violet light for health and vigor and milk treatment, the X-ray, for bulbs and seeds and new plant life, and the infra-red for heat applications. He stated that his company had sold about three-fourths of a million feet of soil-heating cable. He thought that about one million feet was in actual use. He mentioned poultry floor-heating studies, 250-watt lamps used in the California orange orchards, and the electric fence. He stated that he saw the electrical pasteurization of milk only two weeks before and that it was approved by the health authorities. He felt that drying and dehydrating was coming. Mr. Rietz stated that his company was trying to reduce the cost of distribution of electricity; that they were working on two possible methods that looked promising. He told of the fish worm method as applied to strawberry beds. He felt that more information should be gotten out for the farm and town in connection with economic uses of electricity. Advertising, the agricultural colleges, the CREA groups, the utilities groups, the radio, and the development of high school courses were mentioned as important agencies in the distributions of knowledge along these lines.

In the discussion that followed, it was found that there was a serious need for standardization as developments come; that greater volume would produce lower prices and broader uses of electricity in agriculture.

R. L. Perry, assistant agricultural engineer, California Agricultural Experiment Station, gave a report of studies of towers for milk cooling on dairy farms for California conditions where the water supply was limited.

Following the meeting, this writer had the privilege of visiting a number of well-electrified farms in the territory of the Detroit Edison Company. I saw excellent examples of the use of electricity on dairy farms, general farms, and greenhouses and outside plots, and also a very fine example of an electric garden tractor, the cost of which was rather high, but the owner was more than satisfied with the equipment, which was capable of cultivating between 17 and 18 acres from a central trolley system operating 150 ft on each side of the trolley. Hotbeds were proving very satisfactory. In the greenhouse the Puget Sound Power and Light Company soil sterilization system was being used in a double unit for sterilizing flats. They had a soil-mixing machine. They found that it paid to precool flowers, for which purpose they installed extra refrigerating equipment in an old ice cooler. I saw excellent examples of hay hoists, feed grinding and storage, and silo filling.

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RAYMOND OLNEY, *Editor*

R. A. PALMER, *Associate Editor*

Cooperation with the TVA

IN THE NEWS NOTE elsewhere in this issue, mentioning a preliminary conference among representatives of the American Society of Agricultural Engineers and of the Tennessee Valley Authority, is more significant than may appear. Assuming that the joint contact committee is formed and functions as intended, it means that TVA will be able to draw quickly and efficiently on all the resources of organized agricultural engineering.

It is no aspersion on the TVA, but rather inherent in its character as a large-scale laboratory, that it is groping its way into territory largely unexplored. The rapidity with which it can make its experiments, reduce the number of errors, and reach valuable findings, must depend on the extent to which it can tap every resource of established data and expert judgment. In the realm of agricultural engineering—and agricultural engineering is woven all through the project—a quarter-century of organization by the ASAE has made data and judgment promptly accessible. Traced to its end-product of national progress and general benefit, it forms a fruition of the social objective which has been one of the motives in the Society since the first vision of its founders.

While the contact committee is not in purpose an employment agency, it seems obvious that if and when specially qualified talent may be needed by the TVA, the organization of the ASAE and the acquaintance among its membership will be most helpful in locating such talent if available in the Society.

This budding relationship with the TVA is but the latest in a series of increasing number and importance. Federal departments, state agencies singly and in groups, trade associations, and cooperative project committees have utilized the organization and dipped into the resources of the ASAE in sundry ways, always with advantage to all concerned. As a Society we take satisfaction in the contributions we have been able to make through cooperative contacts, and stand ready with further cooperation as opportunity may offer.

For Research in Rubber Traction

LAST FEBRUARY these columns carried a suggestion that there was need for "some studies—something approaching pure research—of the soft rubber tire as a traction device." Thus far it has not come to our notice that any such study as then proposed has begun. In the meantime our conviction has grown that something of the sort should be done.

Such study should do for the rubber tire what J. W. Randolph did for the steel wheel and lug in his investigations at Alabama a decade or so ago; something akin to what M. L. Nichols has been doing for the ultimate benefit of tillage member design. It seems likely that considerable of the methods used and fundamental soil knowledge developed by these men might be borrowed to expedite the study of rubber traction.

On the highway the tire has worked on a surface almost perfectly hard and smooth; at least such is the ideal toward which highways have developed. From the standpoint of the tire, much of the business of farming is to make its footing soft, and often far from smooth. It does not work on a plane, but in a solid, albeit at times more plastic than solid. Surely it would seem that if the men who know rubber tires and those who know soils should get together to map out the fundamentals of rubber traction, it would pay handsomely in greater efficiency and more rapid development.

Eventually we may expect tractors and implements really designed to run on rubber tires. Before the farm equipment industry goes to the vast expense of redesigning to fit the tire, it should have reasonable assurance that the tire has been designed to fit the soil. The design of machines to fit present tires would be little less of a makeshift than has been the design of tires to fit present machines. It should not be necessary for rubber to repeat the history of the steel plow, going through a century of empiricism before its proportions were defined or its action understood.

Misuse of the Term "Labor"

To the Secretary of ASAE:

IN AGRICULTURAL engineering literature and in farm management literature dealing with the expenditure of labor, power, and machinery in agricultural production, the terms "horse labor" and "tractor labor" are used by some writers. There are some objections, as stated below, to the use of the word "labor" in this sense.

Since the agricultural engineer is a specialist in the utilization of farm machinery and farm power, the chief purpose of which is to modify labor requirements in agricultural production, it would seem appropriate for the American Society of Agricultural Engineers to adopt a standard nomenclature in regard to the use of the word "labor." This would also have to be approved by farm management specialists before it could really be standardized. I am suggesting the following standard nomenclature:

In agricultural engineering literature the word "labor" should always mean human labor. Such terms as "horse labor" or "tractor labor" should not be used. "Man-hour" is a unit of labor, but "horse-hour" and "tractor-hour" are units of power, not labor.

Reasons for adopting this standard may be stated as follows:

1 Clear thinking regarding problems of utilization of labor, power, and machinery in agricultural production is promoted by distinct classification of expenditures under

the three headings: Labor, power, and machinery. Lack of specific terms or careless use of terms leads to inaccuracy of classification and to confusion of thought.

2 In common parlance and in general cost accounting the word "labor" has a specific meaning—human labor. It is only in the agricultural field that a practice has grown up of giving the word a more general and therefore less specific meaning by applying it not only to the efforts of human beings but also to the efforts of work animals and tractors that are used for farm power.

3 It is rather uncomplimentary to labor to place it in the same category and under the same word as applied to the efforts of lower animals and inanimate motors.

If you think that this suggestion is of sufficient importance and that the Society might appropriately act upon it, I would suggest that you refer the matter to the proper committee or handle it in whatever way is suitable.

CLAUDE K. SHEDD

Agricultural engineer
Bureau of Agricultural Engineering
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(The foregoing recommendation of Mr. Shedd for the adoption by A.S.A.E. of a standard nomenclature to express units of power is presented here, not so much as a matter of general interest, but more especially to encourage agricultural engineers to comment on Mr. Shedd's recommendation for a standard nomenclature. If the idea seems to meet with general approval of A.S.A.E. members, the proposal will be presented to the Standards Committee of the Society, and eventually to the membership as a whole for approval. The farm managers group will doubtless be asked also to consider taking similar action.—Editor)

Agricultural Engineering Digest

A review of current literature by R. W. TRULLINGER, senior agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture.

NEBRASKA TRACTOR TESTS, 1920-1933. Nebraska Sta. Bul. 285 (1934), pp. 32, fig. 1. This bulletin summarizes the results of 80 tractor tests and includes data on all tractors reported by their manufacturers as on the market January 1, 1934.

MILK HOUSE AND COOLING TANK CONSTRUCTION, *C. H. Jefferson* and *G. M. Trout*. Michigan Sta. Quart. Bul., 16 (1933), No. 2, pp. 88-94, figs. 5. Practical information is given on the construction of a milk house and cooling tank, together with working drawings and a bill of materials.

PEN BARN AND MILKING ROOM, *C. H. Jefferson*. Michigan Sta. Quart. Bul., 16 (1933), No. 2, pp. 84-88, figs. 4. Practical information is given on the pen barn and milking room, accompanied by plan drawings.

AGRICULTURAL ENGINEERING INVESTIGATIONS AT THE ILLINOIS STATION. Illinois Sta. Rpt. 1933, pp. 108, 199-214, fig. 1. The progress results are presented of draft of horses, rural electrification, sewage disposal, tractor lubrication, cost of tractor maintenance, plowing equipment for corn borer control, terracing, grain harvesting, artificial hay curing, stationary spray plants, and swine and poultry structures.

AN INVESTIGATION OF THE PERFORMANCE CHARACTERISTICS OF REINFORCED BRICK MASONRY SLABS: II. A COMPARISON OF THE PERFORMANCE CHARACTERISTICS OF REINFORCED BRICK MASONRY SLABS AND REINFORCED CONCRETE SLABS, *J. W. Whittemore* and *P. S. Dear*. Va. Polytech. Inst., Engin. Expt. Sta. Bul. 15 (1933), pp. 45, figs. 11. The investigations reported in this bulletin were intended as a continuation of studies previously reported. In order to substantiate further the conclusions of the previous studies, tests were made on four reinforced concrete slabs having the same size, type of reinforcement, percentage of steel, and effective depth as possessed by the slabs of reinforced brick masonry previously tested. This made possible a comparison of the various performance characteristics of the reinforced brick masonry and the reinforced concrete slabs.

It was found that over ranges of loading well past design loads, the slabs of both types of construction perform like homogeneous beams in that all relations of load and moment to deflection and stress are linear. The slabs of both types of construction possess ample stiffness even well above design loads. From the viewpoint of induced stresses, both types of construction exhibit very ample safety factors when reinforced concrete theory is used as the basis of design. The various performance characteristics of both types of construction are strikingly similar and in very close agreement throughout the entire range of loading. The formulas of reinforced concrete design are adaptable and applicable to the design of reinforced brick masonry slabs.

AGRICULTURAL ENGINEERING INVESTIGATIONS BY THE DEPARTMENT OF AGRICULTURE. U. S. Dept. Agr., Rpt. Sec. Agr., 1933, pp. 79, 80, 84, 85. A brief account is given of the scope and progress of investigations in soil erosion control at 10 regional erosion stations, in irrigation and drainage, and in cotton ginning and farm machinery.

INFLUENCE OF TETRAETHYL LEAD ON KNOCK RATING, *L. E. Hebl* and *T. B. Rendel*. Jour. Inst. Petroleum Technol., 18 (1932), No. 101, pp. 187-196, figs. 5. Tests with several different gasolines are reported. A factor K was deduced which is practically a constant over a wide range of different gasolines.

$$K = \frac{\log I - \log S}{\log N}$$

in which I is the increase in the highest useful compression ratio of a gasoline treated with tetraethyl lead, S is the effectiveness of tetraethyl lead in raising the highest useful compression ratio of any gasoline, and N represents the number of milliliters of tetraethyl lead added to one United States gallon of gasoline. It is considered likely, therefore, that the factor K may have some fundamental significance in the relationship between highest useful compression ratio and lead susceptibility.

RESEARCHES ON THE INTERNAL-COMBUSTION ENGINE, *C. F. Taylor*. Mech. Engin. (New York), 55 (1933), No. 11, pp. 689-691, figs. 5. The equipment and projects of the internal-combustion-engine laboratory at the Massachusetts Institute of Technology are described.

HEAT EFFECTS IN LUBRICATING FILMS, *A. Kingsbury*. Mech. Engin. (New York), 55 (1933), No. 11, pp. 685-688, figs. 3. An analytical statement of the mathematical theory of heat effects is presented, and an effort made to verify the theory experimentally is described. A specially designed tapered-plug viscometer is described and illustrated, and the results of experiments with mineral oil and olive oil are reported. These apparently verify the theory approximately.

COMPARISON BETWEEN FRICTION AND CONICAL ROLLER BEARINGS FOR FARM WAGONS (trans. title), *G. Bouckaert* and *C. Dricot*. Bul. Inst. Agron. et Stas. Rech. Gembloux, 2 (1933), No. 1, pp. 74-97, figs. 16; Dutch, Ger., Eng. abs., pp. 93-97. Tests conducted at the Gembloux Agricultural Experiment Station are reported.

In experiments on stone pavement and macadam it was found that the reduction in power and draft of wagons due to roller bearings diminished as the grade increased, but increased with the load for a given grade. The mean reduction of the coefficient of traction due to roller bearings was 31.16 per cent on stone pavement and 28.68 per cent on macadam. On pavements with poor surfaces the coefficient of traction increased 17.19 per cent with plain axles and 14.36 per cent with roller bearings. The coefficient of traction was higher on macadam than on stone pavement.

Starting draft trials made on the same roads showed that with roller bearings the draft was practically *(Continued on page 369)*

STUDENT ACTIVITIES

Contributed and edited by A.S.A.E. student members

The Agricultural Engineer — His Field of Activity and Opportunity

By James B. Stere

Student in Agricultural Engineering, Pennsylvania State College

SCANNING the history of the American Society of Agricultural Engineers, we find that the original thought in the minds of the founders seems to have been an organization to serve primarily the particular interest of college teachers. From this we can see that the first demand for agricultural engineers was in the colleges or universities for instructors in service courses to undergraduate agricultural students.

In December 1907 the Society was formally organized. Not long after this date the original idea appears to have given way to that of encouraging closer contact, understanding, and cooperation between agricultural engineers in college and industry.

The commercial and industrial engineers contributed generously to the progress of the Society. The college engineers were limited in number until some of the leaders in this field saw that the educational efforts should not be limited to service courses, but that effort should be made to train men in the fundamental physical sciences, as well as applied engineering courses, in order that engineers so trained might render a technical service to agriculture.

Iowa State College graduated its first three agricultural engineers in 1910. It might be of interest to note that one of these men is head of a division in the Bureau of Agricultural Engineering, U. S. Department of Agriculture; one is head of a department of agricultural engineering at a state institution, and the other is in commercial work.

As activities of the agricultural engineer became more diversified, the Society grew, and it was found that the organization of specialized groups, or divisions, was necessary to accommodate the interests of its members. In 1920 the Land Reclamation Division and the College Division were organized. The Power and Machinery Division and the Structures Division were organized soon thereafter. In 1925 the Rural Electric Division was organized. The scope of agricultural engineering has oftentimes been set forth by considering it under the above headings. This is true but by no means inclusive.

A study of twenty-eight colleges and universities pointed out that possibly the agricultural engineer may generally be classified as (1) the agricultural student, majoring in agricultural engineering, (2) the civil, electrical, mechanical, and other engineers entering the agricultural engineering field, and (3) the student taking the required agricultural engineering curriculum. Let us consider a broad and logical definition that has recently been given by the Bureau of Agricultural Engineering, U. S. Department of Agriculture: "An agricultural engineer is one who is equipped by education and experience to apply the principles of engineering to the conditions, requirements, and objectives of agriculture." After analyzing this definition, we feel safe in excluding the first two classifications from this paper, but not to disregard them.

We find that fifteen out of the twenty-eight institutions included in this study offer a degree and have available information as to the whereabouts and types of positions of their agricultural engineering graduates. Listing these institutions alphabetically we have as follows: University of California, University of Idaho, Iowa State College, Kansas State College, Michigan State College, University of Missouri, University of Nebraska, North Dakota Agricultural College, Ohio State University, Oregon State Agricultural College, Pennsylvania State College, Purdue University, South Dakota State College, Rutgers University, and Virginia Polytechnic Institute. Most of the agricultural engineering degrees have been given by these institutions. To 1933 inclusive, 592 men have graduated in agricultural engineering from these institutions. Eighty-eight of these men have died or their whereabouts and types of position are unknown. The remaining 504 are distributed in the following manner: 108, of 21.4 per cent, are in college and experiment station work; 128, or 25.4 per cent, are in commercial work; 98, or 19.4 per cent, are in federal service; 61, or 12.1 per cent, are farming; 26, or 5.2 per cent, are in public schools, and 83, or 16.5 per cent, are classified as miscellaneous.

College and experiment station work may be subclassified as county agent, extension, instruction, research, and miscellaneous. The information collected was not specific enough to allow us to say what percentage is found under these subclassifications, but it did show that these classifications exist.

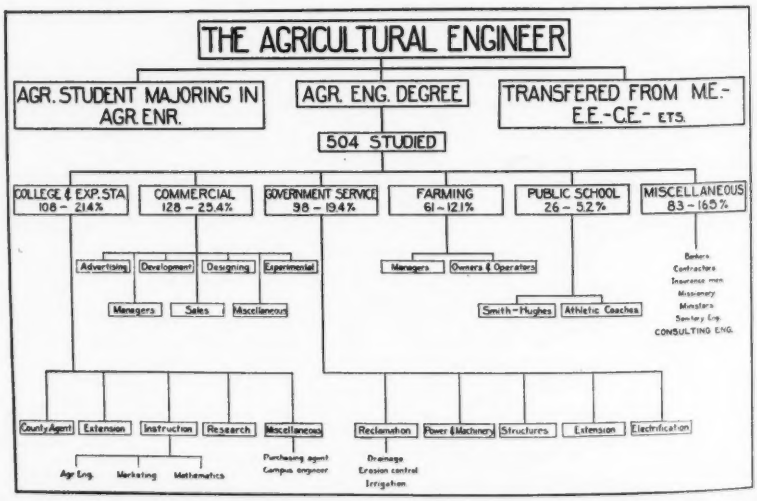
Instruction under college and experiment station may also be subdivided as those teaching in agricultural engineering and those teaching such courses as mathematics, marketing, forest service, and radio. Those in teaching and in research in agricultural engineering may specialize in power and machinery, reclamation, structures, and electrification. Miscellaneous positions such as purchasing agent, campus engineer, and the like indicate other college departments supervised by agricultural engineers.

Commercial work may be subdivided as follows: Development, design, experimental, management, advertising, sales, and miscellaneous. These may also branch into the specialized fields of power and machinery, reclamation, structures, and electrification.

Government service is found to be subclassified in the same manner. Reclamation subdivides as drainage, erosion control, and irrigation. Power and machinery, structures, extension, and electrification may also be subclassified.

Under farming we find managers and owner-operators as the two major classifications. The vocational schools offer fields which may combine athletic coaching with the teaching of farm mechanics.

It is very interesting to note the miscellaneous types of positions filled by some agricultural engineers: Bankers, contractors, insurance men, missionaries, ministers, sanitary engineers, and consulting engineers constitute the majority of this class. Consulting engineers should, no doubt, be a main classification such as college and experiment station, commercial, government service and the *(Continued on page 368)*



CLASSIFICATION CHART SHOWING THE DISTRIBUTION OF AGRICULTURAL ENGINEERS IN THE VARIOUS FIELDS OF THEIR PROFESSION

NEWS

A.S.A.E. Confers with T.V.A.

ON SEPTEMBER 6 and 7, with some activity continuing into the eighth, occurred a conference between representatives of the American Society of Agricultural Engineers and of the Tennessee Valley Authority. The principal place of meeting was the new engineering building of the University of Tennessee, at Knoxville. Attending in behalf of the Society were Leonard J. Fletcher, chairman of the group; G. W. McCuen, president of the Society; Geo. W. Kable, senior designing engineer of the T.V.A.; L. A. Jones of the U.S.D.A. Bureau of Agricultural Engineering; C. E. Seitz of Virginia Polytechnic Institute; J. B. Kelley of the University of Kentucky; R. C. Miller of Ohio State University, and I. P. Blauser, vice-chairman of the A.S.A.E. Rural Electric Division.

On the T.V.A. side attendance was arranged by W. R. Woolrich, chief of the industry division, who himself was present throughout. Other T.V.A. men attending for varying amounts of time, as the scope of subject matter dictated, included J. C. McAmis, chief of the agricultural division, and his assistant, W. M. Landees; H. A. Morgan, one of the three T.V.A. directors; Dr. Curtiss, in charge of fertilizer investigations; and J. P. Ferris of the industrial division. Other T.V.A. men, notably some connected with projects at Norris, attended more briefly.

Dean Chas. E. Ferris, dean of the engineering college at the University of Tennessee, was present during part of the conference and addressed the group.

The purpose of the conference was to promote effective cooperation between the Society and the T.V.A., and especially to devise means for the latter to draw on the technical information, expert judgment, and personnel represented in the Society. Most of the time was applied to becoming thoroughly acquainted, not in a personal sense, but as regards the objectives and problems of the T.V.A. and the subject matter and talent of the A.S.A.E. It was planned to set up a contact committee having for its general chairman Mr. Kable as representative of both organizations, and A.S.A.E. members for the several phases of agricultural engineering technology.

The personnel of the A.S.A.E. group on this committee, as appointed by President McCuen, consists of Leonard J. Fletcher (chairman), representing farm power and machinery; M. L. Nichols, representing farm electrification; R. C. Miller, representing farm structures, and L. A. Jones, representing soil erosion control and other phases of land reclamation. Through this clearing committee any inquiries or communications arising in the T.V.A. will be handled either directly by the committee members, or by reference to other members specifically qualified.

A.S.A.E. Power and Machinery Program

THE Power and Machinery Division of American Society of Agricultural Engineers will present a technical program at The Stevens, Chicago, December 3 and 4. This meeting, as previously announced, will be in the nature of a cooperative meeting with the tractor and industrial equipment group of the Society of Automotive Engineers. Those in charge of arranging the program of both groups are collaborating in this preparation, and there is every assurance that the program will be of great interest to engineers in the tractor and farm machinery industry. The SAE program will be presented at the same place on December 5 and 6.

Division Chairman A. W. Lavers has announced the following as the tentative program for the ASAE Power and Machinery Division:

The forenoon program of Monday, December 3, will consist of two papers, one on testing methods in the manufacture of farm tractor and implement wheels by Col. O. B. Zimmerman, consulting agricultural and mechanical engineer, and another on the effects of the diameter on the performance of tractor drivewheels by E. G. McKibben, associate professor of agricultural engineering, Iowa State College.

The afternoon program of the same day will be devoted exclusively to 1934 developments in the application of pneumatic rubber tires to tractors and other farm equipment. One of the features of this program will be a report of a questionnaire survey among several thousand farm users of rubber-tired equipment, to be presented by C. W. Smith, agricultural engineer, University of Nebraska, as a contribution of the ASAE Committee on Agricultural Wheel Equipment. Reports on individual research studies this past year on rubber-tire applications will be made by I. D. Mayer, agricultural engineer, Purdue University, on experience with rubber tires on a combine; by F. J. Zink, agricultural engineer, Kansas State College, on the use of rubber-tired tractors on listed crop ridges; and by A. W. Clyde, agricultural engineer, Pennsylvania State College, whose subject will be announced later. The session will close with an address by one of the leaders of the farm equipment industry on the future of the rubber-tired tractor.

The forenoon program of Tuesday, December 4, will feature two papers—one a study of power requirements and efficiency of grain threshers, by G. W. McCuen, professor of agricultural engineering, and E. A. Silver, research agricultural engineer, Ohio State University, and another dealing with the geld for small combines by W. M. Hurst, associate agricultural engineer, USDA Bureau of Agricultural Engineering. Frank N. G. Kranick, of the J. I. Case Company, will lead the general discussion of these two papers.

The afternoon program of the same day will feature a symposium on terracing machinery, which is of outstanding interest at this time to engineers in the Land Reclamation Division, as well as in the Power and Machinery Division. Engineers of both groups will participate in the presentation and discussion of this subject. At this session also a paper will be presented by D. C. Sprague, agricultural engineer, Pennsylvania State College, on studies of the adaptation of seeder and cultivator equipment to the one-plow tractor for market gardening.

ASAE—TVA CONFERENCE GROUP

(Standing, left to right) Wallace Robert, TVA agricultural division; Mack Tucker and Max Toole, TVA tests, and (extreme right) H. T. Hendrix, agricultural engineer, University of Tennessee. (Seated, left to right) P. D. Rogers and Robt. La Forge (rear), TVA tests; W. M. Landess, TVA agricultural division; John P. Ferris, industry division; G. W. McCuen, president ASAE; L. A. Jones, chairman, ASAE Land Reclamation Division; C. E. Ferris, dean of engineering, University of Tennessee; W. R. Woolrich, chief, TVA industry division; Geo. W. Kable, chief designing engineer, TVA industry division; Leonard J. Fletcher, chairman, ASAE committee on relations with TVA; C. E. Seitz, past-president ASAE; I. P. Blauser, vice-chairman, ASAE Rural Electric Division; R. C. Miller, agricultural engineer, Ohio State University; and J. B. Kelley, agricultural engineer, University of Kentucky

Farm Structures Division Program

THE Farm Structures Division of the American Society of Agricultural Engineers will present a technical program at a meeting to be held at The Stevens, Chicago, December 3 and 4. This meeting will parallel that of another ASAE division, namely, the Power and Machinery Division.

It is planned to feature four topics of timely interest and importance to agricultural engineers whose activities are allied chiefly to the work of the Structures Division. There are at present four topics to which special attention will be given: (1) grain storage, (2) rural housing, (3) cooperative farm building plan service, and (4) the responsibilities of extension agricultural engineers in present-day farm structures problems.

There is widespread interest just now in the extension of the plans in operation this year to loan money on corn that is stored and sealed on the farm. Structures engineers in grain-growing states are faced with problems in the economical design and construction of storage buildings to meet requirements for storing corn and other grain to be sealed on the farm, which problems will involve not only the protection of such products from weather and rodents, but also to assure its not being removed without permission. The problem also involves possible treatment for weevil control.

The subject of rural housing received attention by the structures engineers at their sessions during the 28th annual meeting of the ASAE at Detroit in June. It is planned to continue these discussions, giving special attention to the federal housing act and also the homestead rehabilitation program.

The cooperative farm building plan service, in spite of the obstacles that have had to be surmounted, is proving its worth and feasibility ,but still requires much constructive thought and cooperative effort on the part of agricultural engineers to fulfill the promise which this effort holds in connection with farm building progress.

In view of the much wider attention that has been given to farm structures problems in recent years, this coming meeting of the Farm Structures Division of the Society promises to be one of outstanding interest and importance to all who are either directly or indirectly interested in structures problems, from both the engineering and economic aspects.

Personals

Harold T. Barr, agricultural engineer, Louisiana Agricultural Experiment Station, is author of Bulletin No. 263, entitled "Corn and Soy Bean Production," dealing with the engineering aspects of the subject, recently issued by that institution.

Deane G. Carter, professor of agricultural engineering and head of the department, University of Arkansas, is author of Bulletin No. 306, entitled "Arkansas Farm House Planning," recently issued by that institution.

G. M. Clarke of the agricultural engineering staff at the University of Georgia has been granted a year's leave of absence to serve as agricultural engineer with the Soil Erosion Service, U. S. Department of the Interior. Mr. Clarke will have charge of the purchase of all field equipment for the various SES projects, with headquarters at Washington, D. C.

A. M. Goodman, agricultural engineer, Cornell University, is one of the authors of Bulletin No. 286, entitled "The Common, or Air-Cooled, Apple Storage, and Its Management," recently issued by that institution.

E. R. Gross and *H. E. Besley,* agricultural engineers, New Jersey Agricultural Experiment Station, are the joint authors of Circular 318, entitled "The New Jersey Multiple Unit Laying House," recently issued by that station.

O. W. Israelsen, irrigation and drainage engineer, Utah Agricultural Experiment Station, is one of the authors of circular No. 106, entitled "Seepage of Groundwater and Its Relation to Alkali Accumulation," recently issued by that institution.

Albert V. Krewatch has recently received a permanent appointment as assistant in agricultural engineering, extension service, University of Maryland, College Park. He was formerly electrical engineer on the National Rural Electric Project.

New ASAE Members

Robert Lamar Green, assistant agricultural engineer, Soil Erosion Service, U. S. Department of the Interior. (Mail) 370 S. Lumpkin, Athens, Ga.

J. C. Oglesbee, Jr., district farm supervisor, Rural Rehabilitation Division, Richmond County E.R.A., 708 Telfair St., Augusta, Ga.

Norman L. Palmer, assistant agricultural engineer, Soil Erosion Service, U. S. Department of the Interior. (Mail) Box 71, Meridian, Miss.

F. W. Peikert, assistant professor, department of agricultural engineering, University of Georgia, Athens, Ga.

Harold J. Shold, senior erosion engineer, State of Iowa Emergency Conservation Work. (Mail) Solon, Iowa.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the September issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Charles T. Bridgman, research fellow (rural structures), agricultural engineering department, Iowa State College, Ames, Iowa.

Arthur T. Mosher, assistant in agricultural engineering, Allahabad Agricultural Institute, Allahabad, India.

J. H. Nicholson, district erosion engineer, Tennessee Valley Authority. (Mail) TVA Building, LaFollette, Tenn.

Chester Y. Vilmont, senior engineer, Iowa Emergency Conservation Work, Camp DPE-77, Johnston, Iowa.

M. F. Visser, professor, Agricultural University; and director, Agricultural Implement Research Station, Wageningen, The Netherlands.

H. D. White, farm mechanics instructor, Abraham Baldwin Agricultural College, Tifton, Ga.

James Donald White, assistant agricultural engineer, Soil Erosion Service, U. S. Department of the Interior, Athens, Ga.

Col. Zimmerman Honored

COL. O. B. ZIMMERMAN, consulting agricultural and mechanical engineer, and a past-president of ASAE, was signally honored at a meeting on October 2 of the Mid West Section of the Society of Automotive Engineers, held at the Hamilton Club, Chicago. At this meeting Col. Zimmerman was the guest of honor, and for distinguished service in the field of automotive engineering he was presented with a life membership in the Society of Automotive Engineers, the presentation being made by Delmar G. Roos, president of SAE. Mr. John A. C. Warner, general manager of SAE, also spoke in high appreciation of Col. Zimmerman's outstanding engineering record.

The Agricultural Engineer

(Continued from page 366)

like, but so far only three of these men are in this type of work.

The trend of the field as indicated by the employment of agricultural engineers for the past several years shows that government service employs the largest percentage of the men. This may be due to several reasons that require no discussion. It does show, however, that the government recognizes these men as having had training of a definite value.

The progressively expanding field of agricultural engineering together with its established activities, offers distinct opportunities for the future.

The perfection of personnel should lead to the realization of our professional consciousness, the responsibilities which it carries, and the importance of the service that it renders to agriculture.

It may not be amiss here to call attention to the excellent amount of available material which exists in other languages This material has been used to an advantage perhaps only by a very few agricultural engineers in America. Little thought was given in the past to the important contributions that were made by important engineers of foreign countries; consequently a study of foreign languages was not deemed necessary but now becomes desirable. In this direction there is an opportunity to assimilate, correlate, and develop professional literature for guidance and service of the agricultural engineering profession.

In the perfection of present equipment and the development of newer ideas, we have unlimited opportunities. There is a constant discovery of new principles, and the application of old principles to newer fields which demands the development of machinery either by redesigning existing equipment or devising new types to meet the demand of the future.

As an illustration, the newer methods recently proposed in the application of insecticides and germicides will serve as an example. It has been observed that infinitely small particles in spray materials may be obtained for atomization, with considerably lesser expenditure of energy if the spray material possess some kinetic energy through the application of heat before it enters the spray nozzle. This simple illustration alone indicates the possible new fields for the agricultural engineer in other lines of agriculture. The agricultural engineer has successfully invaded the field of agriculture and has contributed much to its advancement. The future of our profession offers a challenge to young men of ability.

Agricultural Engineering Digest

(Continued from page 365)

proportional to the load, and that with plain axles the draft increased more rapidly than the load. The mean coefficients of starting with both types of bearings were greater on the pavement than on the macadam.

The reduction of the coefficient of traction obtained with roller bearings was greater in normal rolling on both pavement and macadam than in starting. The differences due to condition of the road surface were more important in starting than in normal rolling.

Field trials, while not conclusive, indicated a reduction of the coefficient of traction due to roller bearings.

GUM FORMATION AND ITS INHIBITION IN MOTOR SPIRITS, *W. H. Thomas.* Jour. Inst. Petroleum Technol., 18 (1932), No. 103, pp. 350-356. This is a summary of the findings of others on the subject, accompanied by a bibliography of forty-five references.

STUDIES ON THE TREATMENT OF BEET SUGAR FACTORY WASTES. *E. F. Eldridge* and *F. R. Theroux.* Mich. Engin. Expt. Sta. Bul. 51 (1933), pp. 36, figs. 5. The results of investigations extending over two years are reported which involved a study of some of the methods which could be applied to the treatment of the process water, which was found to contain the major portion of the organic matter discharged from the sugar beet factory. A summary of the results of work reported by others is also included, together with a bibliography.

Laboratory and experimental plant studies on chemical precipitation processes showed the minimum quantity of lime required for coagulation of the colloidal materials was about 600 p.p.m. The addition of ferric chloride even in amounts as small as 15 to 20 p.p.m. gave much better clarification than when lime alone was used. The floc was much heavier and settled more rapidly, leaving a well-clarified supernatant liquor. The average reduction in biochemical oxygen demand after 30 min settling was 71 per cent, after 1 hr 80 per cent, and at the end of 2 hr it gave practically no further removal. The degree of biochemical oxygen demand removal depends upon the sucrose content of the initial waste. With the average sugar content of about 400 to 500 p.p.m., a removal of from 80 to 82 per cent was obtained with about 2 hr settling.

Experiments on the activated sludge process showed that the outstanding factors which are not favorable to the use of the process for beet-sugar-factory process water are the difficulty of operation resulting from the tendency of the waste to foam and the high cost of the equipment necessary to provide a 12 hr aeration period for a volume of waste twice that of the process water. With the equipment used in the studies, it was impossible to correct the foaming to the extent that it would not interfere with aeration.

Experiments on the digestion of mixtures of sewage and process water sludges showed that process water up to approximately 10 per cent by volume may be mixed with sewage without having any apparent effect on the digestion of the sludge. Mixtures containing from 14 to 53 per cent process water have slightly retarding effects on gas production during the initial periods of digestion, but within four weeks produce approximately the same quantity of gas as that from sewage sludge containing the same weight of volatile matter. For a mixture containing as high as 70 per cent process water the digestion action is very seriously retarded.

It is considered evident from these results that sugar beet process water can be added to sewage in approximately equal volumes without seriously affecting the digestion of the sludge.

SOME EXPERIMENTS ON THE RESISTANCE TO WEAR OF NITROGEN-HARDENED CAST IRON, *J. E. Hurst.* Engineering (London), 137 (1934), No. 3548, pp. 50, 51, fig. 1. Laboratory and field experiments on the resistance to wear of nitrogen-hardened cast iron are reported, which were arranged to study the behavior of these materials under wear conditions such as exist in internal-combustion-engine cylinders.

All the tests were carried out on the material in the form of cylinder liners of the type known, as dry liners. The procedure followed in an individual test consisted of fitting up the four bores of the engine with liners. In one bore a liner of one of the standard materials was fitted, and in the remaining three bores were fitted liners of the materials to be tested. The engine was then run under steady, approximately full-load conditions for a given number of revolutions. Each unit test consisted of a period of 40 x 106 engine revolutions.

Four standard types of material were used in the experiments as a basis of comparison with the nitrogen-hardened cast irons employed. These comprised (1) plain, unalloyed centrifugal cast iron, (2) chromium-alloy cast iron, centrifugally cast, in the as-cast condition, (3) chromium-alloy cast iron, centrifugally cast, in the hardened and tempered condition, and (4) nickel-chromium-alloy cast iron, centrifugally cast, hardened, and tempered to a Brinell hardness of from 450 to 500.

On the basis of 30,000 miles of operation, the results were 27,000 miles per 0.001 in of wear for the nitrogen-hardened cast iron and 12,125 miles per 0.001 in for the chromium-alloy cast iron. The chromium-alloy centrifugal cast iron gave results very little different from those of the unalloyed centrifugally cast material.

In two road tests the resistance to wear of nitrogen-hardened cast iron was compared with those of chromium-alloy and nickel-chromium-alloy cast irons in the hardened and tempered condition. The tests were made in six-cylinder engines using three nitrogen-hardened cylinder liners in each cast.

The results show that the differences between the wear values of ordinary cast iron, alloy cast irons, and hardened and tempered cast irons of the types experimented with, are not of a very large order. These results demonstrate clearly the improved resistance to wear under internal-combustion-engine cylinder conditions of cast iron surface-hardened by the nitrogen-hardening process. They also may be used to demonstrate the stability of the nitrogen-hardened surface under these same conditions.

DESIGN AND OPERATION OF DRAINAGE PUMPING PLANTS IN THE UPPER MISSISSIPPI VALLEY, *J. G. Sutton.* U. S. Dept. Agr. Tech. Bul. 390 (1933), pp. 60, pls. 8, figs. 30. The results of a study of seventeen representative drainage pumping plants in the upper Mississippi Valley extending over a period of six years are presented, the purpose being to present technical information on the elements to be considered in the design of such plants, data for use in determining these elements in the upper Mississippi Valley, the selection and design of drainage pumping equipment, and the construction and operation of pumping plants.

It is pointed out that a drainage pumping plant should be designed to pump the estimated maximum run-off rate at the maximum lift. In the upper Mississippi Valley, minimum lifts range from 0 to 9 ft, and maximum lifts range from 12 to 25 ft. The average lift during the low-water season for a period of years should be the basis for designing a low-lift pumping unit in a multiple-unit plant.

The annual run-off to be pumped should be determined in order to estimate the annual plant factor and cost of pumping. The estimated average run-off pumped from districts that were affected by backwater from dams ranged from 16 to 35 in per year, and from districts not affected greatly by backwater ranged from 12 to 16 in. The annual run-off from districts that obtained some gravity drainage and were not affected by backwater from dams was estimated as from 5 to 15 in.

The distribution of run-off according to static lift should be determined in order that the plant can be designed for maximum efficiency at the lift at which the greatest amount of pumping must be done, and that one or more units can operate efficiently at any lift.

The required capacity for a drainage pumping plant in the upper Mississippi Valley, at maximum lift, in terms of average total run-off pumped per year and a coefficient varying with size of drainage area and degree of protection provided for the lands, may be computed as $C = K_1 (0.22 + 0.006r)$. A formula for general application is $C = K_1 [K_2 + K_3 (r - a)]$.

In these formulas

C = plant capacity at maximum lift, in inches depth of run-off for 24 hr

K_1 = size and adequacy coefficient, depending upon area drained and adequacy of drainage

K_2 = rainfall-run-off coefficient, equal to the run-off capacity for all-gravity systems draining similar areas and topography

K_3 = seepage coefficient, indicated by the slope of the line of recommended capacities

r = total annual run-off to be pumped, in inches depth over the drainage area

a = number to be determined empirically for each particular region

An appendix includes data on drainage pumping plants in the upper Mississippi Valley in 1930.

THE FLOW OF WATER IN FLUMES, *F. C. Scobey.* U. S. Dept. Agr., Tech. Bul. 393 (1933), pp. 99, pls. 16, figs. 8. This is a technical treatise on flumes with particular reference to their carrying capacity for water. It includes an account of detailed field measurements and experiments and mathematical and hydraulic analyses leading to the elucida- *(Continued on page 372)*

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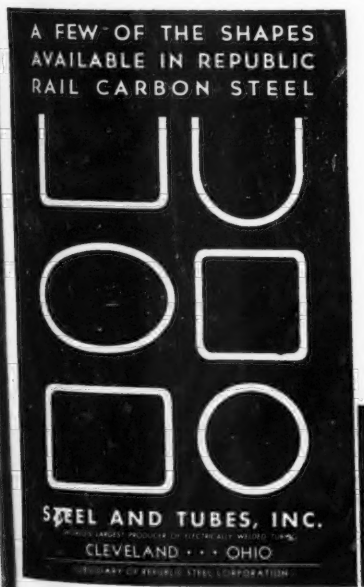

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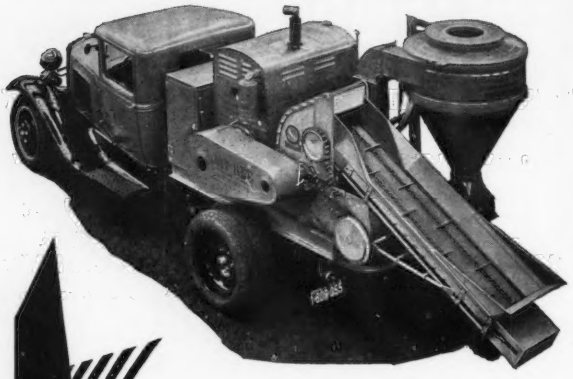
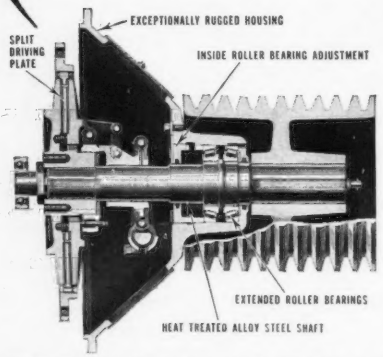


"When we were designing the Jay Bee Portable Hammer Mill with gasoline engine power, we adopted the Twin Disc Clutch because of Twin Disc high standing in the industry, your experience and the availability of service, if required," says W. J. Clement, Chief Engineer of J. B. Sedberry, Inc., Utica, N. Y. "The Twin Disc Clutch gives us a flexible means of starting our mill and permits us to stop the mill without stopping the power unit, which of course saves time as well as wear and depletion of the electrical starting equipment; of course it also prolongs the life of the drive belts." Twin Disc Engineers' sixteen years of specialized experience in building clutches and power take-off units is at your disposal. *Write* for specific recommendations. Engineering data on request. *Twin Disc Clutch Company, 1340 Racine Street, Racine, Wisconsin.*



No. 8052 Twin Disc Power Take-Off Unit

TWIN DISC CLUTCHES

Agricultural Engineering Digest

(Continued from page 369)

tion of the elements and basic principles of flume design for various purposes and conditions.

The flow of elements entering the design of the flume proper consist of quantity, Q, usually given in the conditions of the problem; the hydraulic radius, R, computed from the formula $R = A/p$ for the tentative section being tried in computations when A is the area of water cross section and p the wetted perimeter; the velocity, V, computed from $V = Q/A$ for the tentative section; an assumed value of the frictional factor, n; and the slope, $S = s$, for uniform flow, resulting from the solution of a standard flow formula such as Kutter's or Manning's.

New Methods in Electro-Culture, *S. S. Nehru.* Jour. Roy. Soc. Arts, 82 (1934), No. 4234, pp. 231-252. An account is given of several experiments employing sparking, radiation, and radiomagnetic methods of electro-culture with various crops, involving a consideration of so-called soil and plant "energetics." No very definite conclusions are drawn from the experiments, but recommendations are made as to equipment which may be used for the different methods proposed.

Our Experience With Canvas Hose Irrigation in the Orchard, *C. E. Dutton.* Ohio State Hort. Soc. Proc., 66 (1933), pp. 70-78. An account is given of practical experiments made in a commercial orchard with canvas hose irrigation.

The Effect of Varying Compression Ratio and Inlet Temperature on Engine Performance, *G. W. Hobbs* and *M. L. Surls.* Mich. Engin. Expt. Sta. Bul. 50 (1933), pp. 15, figs. 6. Investigations to determine the effect of such variables as air-fuel ratio, spark setting, temperature of intake air, and the like, on engine performance over a considerable range of compression ratios are reported.

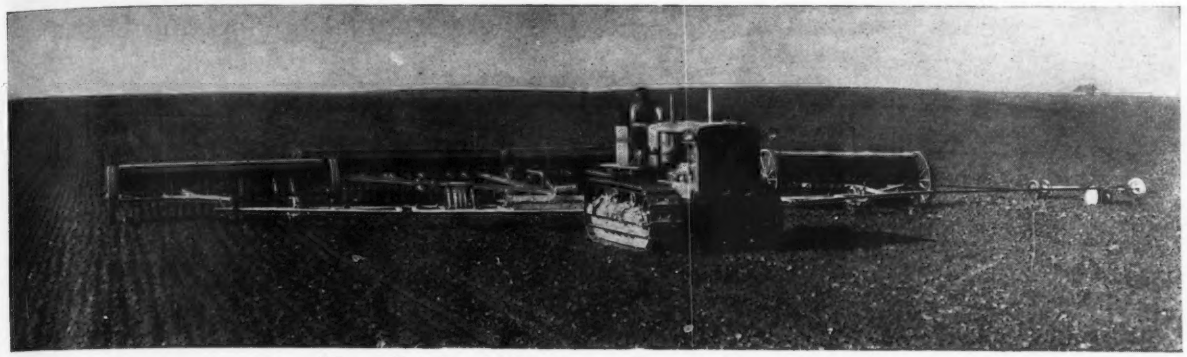
The results show that the brake mean effective pressure is increased by increasing the compression ratio, and the increase is much more pronounced at the lower than at the higher ranges. A very slight increase is registered between compression ratios of 7 to 8.65. The higher compression ratios give better economy (pounds of fuel per brake horsepower-hour) than the lower ratios. The general characteristics are the same as for brake mean effective pressure. The brake mean effective pressure increases with the spark advance up to the point of detonation, and beyond that point decreases rapidly. The rate of decrease in brake mean effective pressure after detonation begins, increases with the compression ratio. Detonation is the most severe when operating with an air-fuel ratio and with a spark setting that would give maximum power if no detonation occurred. The spark setting and carburetor setting should be adjusted for each fuel in order to get the best results. The air-fuel ratio for maximum power and for maximum economy are independent of the compression ratio. Heating of the intake air or of the intake mixture does not affect the air-fuel ratio for either maximum power or economy, but does increase the tendency to detonate.

The volumetric efficiency of the engine increases as the compression ratio decreases. The change in volumetric efficiency between low and high compression ratios is independent of the jacket temperature, and is the same when the engine is motoring as when firing. This increase in volumetric efficiency is caused by the inertia of the incoming charge. There is a greater pumping or ramming action operating with the increased total cylinder volume at the low compression ratios.

From constant brake mean effective pressure values on constant spark advance curves, it was found that the same power may be obtained from an engine by using a small spark advance and high compression or a greater spark advance and a low compression. It also holds that the increase of the usable compression ratio with retardation of ignition, when ignition is already late, is accompanied by a decrease instead of an increase in power. On the other hand, when the ignition is advanced the decrease of compression ratio necessary to use this advance is also followed by a decrease in power.

Agricultural Engineering Investigations at the Arizona Station. Arizona Sta. Rpt. 1933, pp. 16-20, 25-27, 30. The progress results are briefly presented of studies of ground water, pumping machinery, downward movement in and water-holding capacity of soils, financial rehabilitation of irrigation and drainage districts, and land leveling and water penetration.

Agricultural Engineering Investigations at the South Dakota Station, *R. Patty* and *W. C. Tully.* South Dakota Sta. Rpt. 1933, pp. 8-11, 33, 34. The progress results are briefly presented of investigations on the use of the combine harvester-thresher; rammed earth for farm building walls, including poultry houses especially corn-harvesting ma- *(Continued on page 374)*



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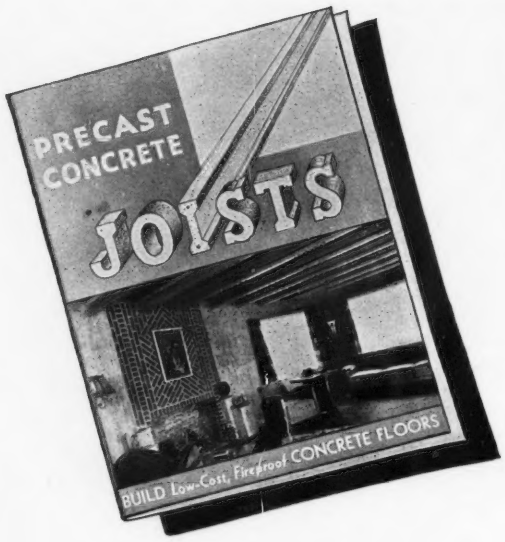

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Agricultural Engineering Digest

(Continued from page 372)

chinery; field machinery for tractor and large horse teams; and the comparative length of service of galvanized steel posts and painted steel posts.

AGRICULTURAL ENGINEERING INVESTIGATIONS AT THE NEW YORK CORNELL STATION. (New York) Cornell Sta. Rpt. 1933, pp. 72, 73. The progress results are briefly presented of investigations on dairy, stable, and poultry house ventilation, farm power machinery, milk-cooling equipment, and electric brooding of chicks.

A DIKER-RIDGER, *H. E. Murdock*. Montana Sta. Bul. 281 (1933), pp. 12, figs. 10. The construction and use of homemade grader-dikers are described and illustrated. This equipment is used to construct dikes around dry farm areas for the retention of precipitation water which otherwise would run off.

ESTIMATED DATA ON THE ENERGY, GASEOUS, AND WATER METABOLISM OF POULTRY FOR USE IN PLANNING THE VENTILATION OF POULTRY HOUSES, *H. H. Mitchell* and *M. A. R. Kelley*. Jour. Agr. Res. (U. S.) 47 (1933), No. 10, pp. 735-748. This paper, which is a joint contribution from the Illinois Experiment Station and the U. S. D. A. Bureau of Agricultural Engineering, contains estimations of the gaseous, energy, and water metabolism of poultry for use by the agricultural engineer when designing heating or ventilating systems for poultry houses.

The calculations are based mainly on metabolism studies conducted at the station with Plymouth Rock and White Leghorn chickens, the Bronze turkey, the Pekin duck, and the Embden and Toulouse geese. The data assembled are discussed from the engineering viewpoint and their practical use by the engineer demonstrated.

TESTS ON BRICK MASONRY BEAMS, *M. O. Witey*. Amer. Soc. Testing Materials Proc. 33 (1933), pt. 2, pp. 651-665, figs. 5. In a contribution from the University of Wisconsin, data are reported on the shear and bending strengths of twenty-five 8-by-12-in reinforced brick beams tested under third-point loading over an 8-ft span.

Three widely different varieties of brick, and several variations in percentage of longitudinal steel between 0.5 and 2.3 per cent, as well as different percentages of stirrup reinforcement, were used. The tests indicate that a high degree of flexural strength and shear strength can be developed in reinforced brick beams, provided due attention is paid to mortar bond, coursing, amount and arrangement of reinforcement, and filling of joints. Formulas for reinforced concrete design with appropriate constants can be used to calculate stresses and deflections of reinforced brick beams.

ADOBE OR SUN-DRIED BRICK FOR FARM BUILDINGS, *T. A. H. Miller*. U. S. Dept. Agr., Farmer's Bul. 1720 (1934), pp. 18, figs. 22. This bulletin describes the method of making and using adobe in the form of sun-dried bricks. The material consists of a mixture of clayey loam, straw, and water, and is said to be of proven value as a material for walls.

A STUDY OF COAGULATION AS APPLIED TO SEWAGE TREATMENT, *E. F. Eldridge* and F. R. Theroux. Mich. Engin. Expt. Sta. Bul. 55 (1934), pp. 22, figs. 7. Laboratory studies and service tests of chemical coagulation of sewage as an adjunct to regular treatment are reported.

The laboratory studies indicated a definite pH zone in which ferric chloride coagulation of sewage is most effective, which for the experimental sewage was between 6.5 and 8.

There are two pH zones in which good removal of turbidity and suspended solids are obtained. One is the higher optimum range and the other a much lower range. These two zones are separated by a zone of low removal. This zone of low removal may be due to a coagulation of sewage colloids at their isoelectric point without the aid of the ferric chloride. Ions extend the range of flocculation. Negative ions extend the range toward the lower pH values and positive ions toward the higher. Ions of higher valences have a greater effect on extending the range. Potassium permanganate in small amounts allowed the flocculation of a water at normal pH (7.8) when otherwise flocculation occurred at pH 4.5 to 5.5.

In the experimental plant work it was found that greater amounts of solids may be removed from sewage by the use of ferric chloride than by plain sedimentation. The removal of suspended solids increases with increasing doses of ferric chloride up to at least 1.25 grains per gallon. The removal for this dose was about 90 per cent. The biochemical oxygen demand is greatly decreased, indicating the removal of organic colloids as well as suspended solids. Odors in the settled sewage are decreased by the use of ferric chloride.

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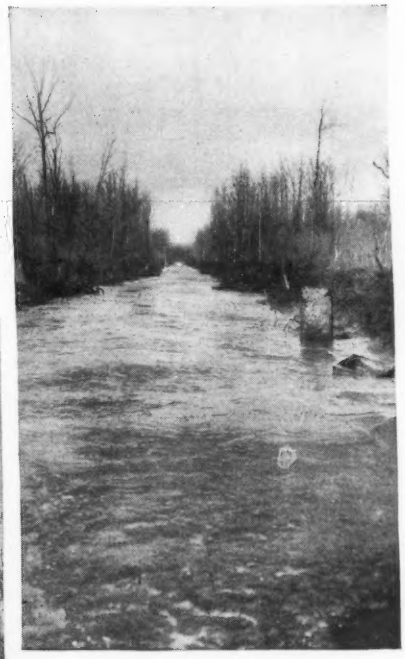

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DESPITE the *presumption* it sets up, mere membership in the American Society of Agricultural Engineers is no *proof* of a man's high rank in technical talent. It does prove that he has met certain minimum requirements and has earned the esteem of colleagues who sponsored his application for membership.

But the Society emblem is *evidence* that native talent, be it great or small, is enriched by fraternity with the personalities whose minds fuse to form the pattern of progress in the methods and mechanics of agriculture. The wearer of the emblem waits not for the debut of an idea, but is present at its birth and helps to guide its growth.

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ASAE

EMPLOYMENT BULLETIN

An employment service is conducted by the American Society of Agricultural Engineers for the special benefit of its members. Only society members in good standing are privileged to insert notices in the "Men Available" section of this bulletin, and to apply for positions advertised in the "Positions Open" section. Non-members as well as members, seeking men to fill positions, for which members of the Society would be logical candidates, are privileged to insert notices in the "Positions Open" section and to be referred to persons listed in the "Men Available" section. Notices in both the "Men Available" and "Positions Open" sections will be inserted for one month only and will thereafter be discontinued, unless additional insertions are requested.

Men Available

ELECTRICAL ENGINEER, graduate of the University of London, desires employment as rural service engineer or distribution engineer with an electric power company, or as research engineer in rural electrification with an agricultural experiment station, preferably in eastern or western United States. Seven years experience in rural electrification with electric power companies and in research at a state agricultural college. Age 33. MA246.

RURAL ELECTRIFICATION ENGINEER with bachelor's degree from an eastern state college (1928) now employed by one of the largest public utilities in the East, desires a change of location. He is experienced in all farm operations, thoroughly understands rural problems, has had six years' experience in rural electrification, and has also taken the rural electrification course offered by General Electric Company. He would be interested preferably as rural electrification engineer with a public utility, in experiment station research work, with an equipment manufacturing concern, or as a graduate assistant. Age 29. Single. Will go anywhere. MA-253

AGRICULTURAL ENGINEER desires employment in soil erosion control work, soils, drainage, or any other phase of land reclamation. He is a 1915 graduate in forestry of the University of Washington; has had extensive experience in land clearing, drainage, and heavy construction work; has made an intensive study of soils, drainage, etc., and for the past ten years has been engaged in private professional practice as a civil and landscape engineer, and is a registered civil engineer and land surveyor in the states of New Jersey and New York. Age 40. Married. Prefers location in the East, but will go anywhere. MA-254

AGRICULTURAL ENGINEER, graduate of a midwest university, with several years' experience teaching farm mechanics in state agricultural college and with wide experience in testing, extension, research, and editorial work, desires position in state agricultural college or federal work, or with commercial firm where his training and experience can be capitalized. MA-255

AGRICULTURAL ENGINEER with bachelor's degree in mechanical engineering and in agricultural engineering, and a master's degree in engineering, graduating with high honors from University of Wisconsin. For 18 months and at present camp superintendent on federal erosion control CCC camps in Wisconsin and Illinois in charge of concrete and construction work for erosion control and land utilization directing 220 men and 10 engineers. Assisting instruction work during graduate work at University of Wisconsin, three years' research and experimental engineering and design of all sizes of Diesel engines with America's largest builder. Two years' graduate research on small grain grinding. Best of references. Desires more permanent connection with work requiring man with excellent contact ability, sales engineering, insurance company, industrial firm. Age 27. Location not important. MA-256.

Positions Open

ENGINEER wanted. Must have experience in design, development, and experimental work relating to farm machinery, preferably tillage. Must be 35 to 40 years of age, have experience in handling men, and ability to cooperate with production departments. Graduate engineer desired, but not necessary. In replying, give age, education, experience in detail, salaries received and expected. PO-101

AGRICULTURAL ENGINEER (graduate) wanted with practical experience in the planning of farm buildings, including heating and ventilation. Must have ability to address public gatherings, instruct, and sell. PO-102